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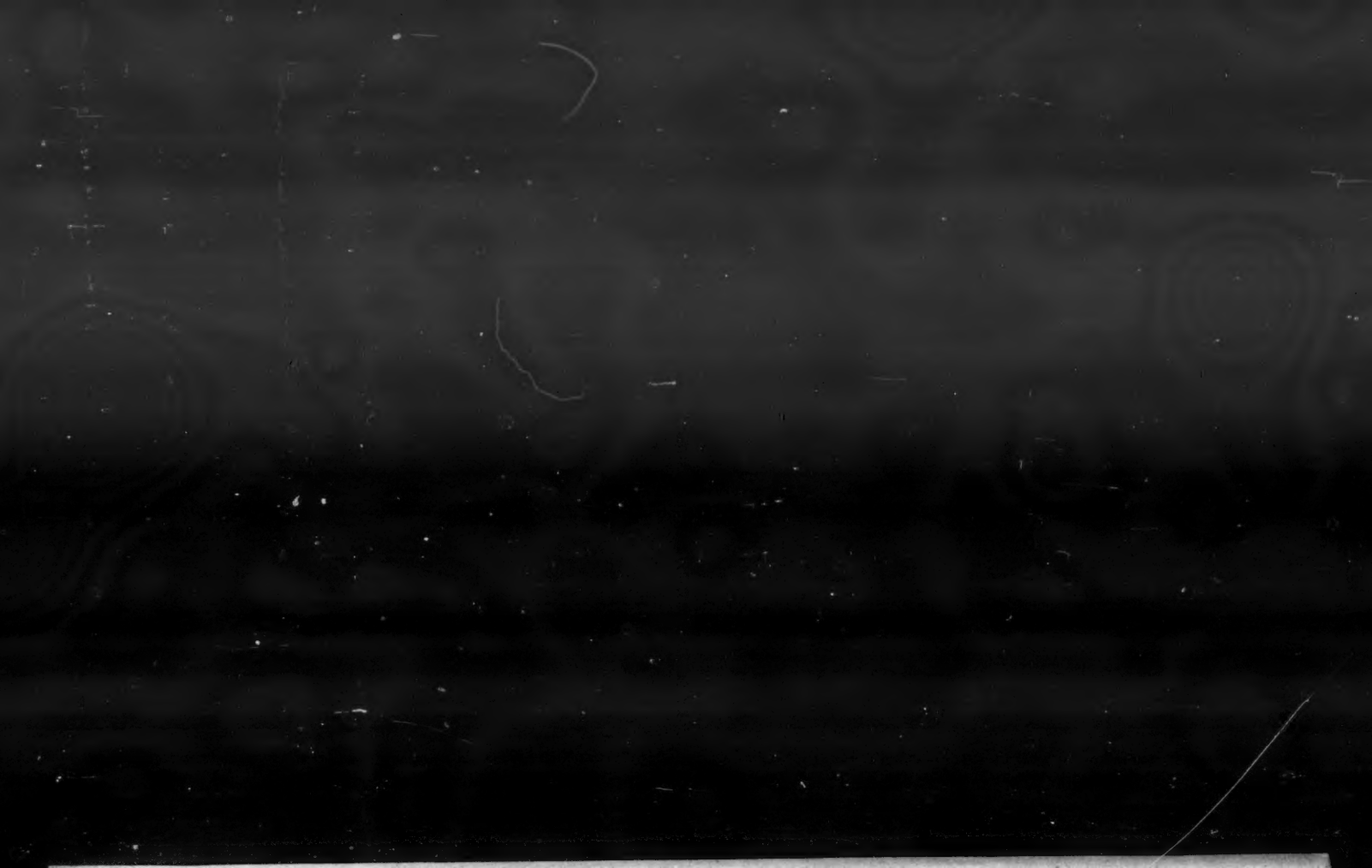

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. I.—*The Worship of Meteorites;* by HUBERT A. NEWTON.

[A lecture delivered* in New Haven, Conn., March 29, 1889.]

HERE is a small fragment of iron that has a curious history. It is a portion of a mass of meteoric iron found upon a brick altar in one of the Ohio mounds. Along with it were various objects—a serpent cut out of mica—several terracotta figurines—two remarkable dishes carved from stone into the form of animals; pearls, shells, copper ornaments, and nearly three hundred ankle bones of deer and elk. There were but one or two fragments of other bones, and one animal furnished but two of these ankle bones; hence they must have been selected for some special, important reason. The figurines had been apparently broken for some purpose, and the whole collection had suffered in the fire not a little. In a like altar of another mound of the same group were found nearly two bushels of like objects.

It must have been in some ceremony of a religious, possibly one of a funereal, character that the mound builders collected here on the altar their ornaments and other valuables, and after burning them buried the charred debris in the huge earthern mound that was built over them and the altar.

* This lecture has not hitherto been published; perhaps the author regarded it as hardly falling within the sphere of a scientific journal. Even if this be the case, however, the general interest of the subject is such as to justify its being printed now. Further, it seems due to the author that the scientific public should have the benefit of all his contributions to the subject to which he gave so much study. It may be added that the biographical notice of Professor Newton, it is expected, will appear in the May number.—EDITORS.

What would we not give if this fragment could be endowed with the power of repeating to us its experience,—chapters in the history of that people? But nearly all that we can say is that it was found among objects held by them in peculiar esteem, and used by them in some serious, probably religious ceremony.

There was formerly, and so far as I know there is still, in the collection of meteorites in Munich, a stone that weighs about a pound. It fell in 1853 in the region north of Zanzibar on the East African coast, and was seen and picked up by some shepherd boys. The German missionaries tried to buy it, but the neighboring Wanikas, because it fell from heaven, took it to be a god. They secured possession of it, anointed it with oil, clothed it with apparel, ornamented it with pearls, and built for it a kind of temple to give it proper divine honors. The agents of the missionaries were not allowed even to see the stone, far less could they purchase the Wanika's tutelar deity. Neither entreaties, nor arguments, nor offers of the missionaries, nor of the officials were of any avail. But when three years later the wild nomad tribes of the Masai came down upon the Wanikas, burned their village, and killed large numbers of them, the Wanikas thought very differently of the stone's protecting power. In fact they lost all respect for it. A famine having meanwhile arisen, the elders of the tribe were quite ready to exchange their palladium for the silver dollars of the missionaries.

Among the Buddha legends is one of two merchants who offered food to the Buddha, which was accepted, and in consequence of their request for some memorial of him the Buddha gave them a hair and fragments of his nails, and told them that hereafter a stone should fall from heaven near the place where they lived, and that they should erect a pagoda and worship these relics as though they were Buddha himself.

The nations of India have always been specially superstitious about stones fallen from the skies. In 1620 an aerolite fell near Jullunder, and the king sent for a man well known for the excellent sword blades that he made, and ordered him to work the lump into a sword, a dagger and a knife. The mass, however, would not stand the hammer, but crumbled in pieces. By mixture with iron of the earth the required weapons were made.

In 1867 a shower of stones fell, some forty in number, at Saonlod. The terrified inhabitants of the village, seeing in them the instruments of vengeance of an offended deity, set about gathering all they could find, and having pounded them into pieces they scattered them to the winds.

In 1870 a meteorite fell at Nidigullam, and the Hindoos at

once carried it to their temple and worshiped it. The same has been repeated in India on the occasion of several other stonefalls in the present century. One native ruler refused to allow a stone to be carried across his territory for fear of the injury that might come to his people or his lands.

Two Japanese meteorites, formerly the property of a daimio family, were long kept and handed down as heirlooms, being in the care of the priests in one of the family temples. They were among the family offerings made to Skokujo on her festival days. They were connected with her worship by the belief that they had fallen from the shores of the Silver River, Heavenly River, or Milky Way, after they had been used by her as weights with which to steady her loom. One of these stones was presented by its late owner to the British Museum, and it is in its collection of meteorites.

There is a curious institution among the Chinese that has existed, according to Biot, from a time more than one thousand years before Christ. The Chinese attributed to different groups of stars a direct influence upon different parts of the empire. Some of these groups correspond, for example, to the imperial palaces, to the rivers, the roads, and the mountains of China. By reason of this belief regular observations are made by the imperial astronomers of all that passes in the heavens, especially of the groups of stars in which comets and meteors originate, or across which they travel. The interpretation of what is seen in the sky forms part of the duties of these very important officials. These observations have been carefully written out, and are preserved in the archives of the empire. Upon the ending of a dynasty, by change of name or otherwise, these comet and meteor records have been published as a special chapter of the chronicles of the dynasty. The existing dynasty began in 1647, since which date the records are, therefore, unpublished.

In 1492 a stone of 300 pounds weight fell at Ensisheim, in Alsace. The Emperor Maximilian, then at Basel, had the stone brought to the neighboring castle, and a Council of State was held to consider what message from heaven the stonefall brought to them. As a result the stone was hung up in the church with an appropriate legend and with strictest command that it should ever remain there intact. It was held to be an omen of import in the contest then in progress with France and in the contest impending with the Turks. Nineteen years later a shower of stones fell near Crema, east of Milan. The pope was at war with the French and the stones fell into the French territory. Before the year had passed the French, after a long possession of Lombardy and serious threatening of the States of the Church, were forced to retire from Italy. At

this time Raphael was painting for an altar-piece his magnificent Madonna di Foligno now in the Vatican. Beneath the rainbow in the picture, indicating Divine reconciliation, Raphael painted also this Crema fireball apparently to set forth Divine aid and deliverance.

I have thus rapidly gone over some selected facts showing how the mound-builders, the wild Africans, the Hindoos, the Japanese, the Chinese, the modern Europeans have been ready to revere these myfterious bodies that come from the skies. But it is in the Greek and Latin literature that we have reason to expect the more numerous and full accounts, both legendary and historic, of this reverence and worship.

It is now I believe admitted by the best scholars that both in Greece and in Italy, there was a period earlier than the age of images, when the objects worshiped were not wrought by hand. Men worshiped trees and caves, groves and mountains and also unwrought stones. Even after men began to make their objects of worship, these were in many cases mere hewn stones, not images. The earlier Greek term ἄγαλμα, an object of worship, stands apart from the later term εἰκών, image.

What would be more natural in that age to the affrighted witnesses of the most magnificent of spectacles, the fall of a meteorite, than for them to regard the object which had come out of a clear sky, with terrific noise and fire and smoke, as something sent to them by the gods to be revered and worshiped? It was nobler to worship a stone fallen from the sky than one of earthly origin.

The worship of an unwrought stone once established has wonderful vitality. For example, the Greek writers speak of such a worship in their day among the Arabian tribes. When Mohammed with his intense iconoclasm came down upon Mecca and took the sacred city, he either for reasons of policy, or from feeling, spared the ancient worship of this black stone. Entering into the sacred inclosure he approached and saluted it with his staff (where it was built into the corner of the Kaaba), made the sevenfold circuit of the temple court, returned and kissed the stone, and then entered the building and destroyed the 360 idols within it. To-day that stone is the most sacred jewel of Islam. Toward it each devout Moslem is bidden to look five times a day as he prays. It is called the Right Hand of God on Earth. It is reputed to have been a stone of Paradise, to have dropped from heaven together with Adam. Or, again, it was given by Gabriel to Abraham to attest his divinity. Or, again, when Abraham was reconstructing the Kaaba that had been destroyed by the deluge, he sent his son Ishmael for a stone to put in its corner, and Gabriel met Ishmael and gave him this stone. It was originally transparent hyacinth, but

became black by reason of being kissed by a sinner. In the day of judgment it will witness in favor of all those who have touched it with sincere hearts, and will be endowed with sight and speech. The color of this stone, according to Burckhardt, is deep reddish brown, approaching to black; it is like basalt, and is supposed by some to be a meteorite.

It is not important for my purpose to separate the history from the myth. Eusebius quotes from an old Phœnician writer, Sanchouniathon, that the Goddess Astarte found a stone that fell from the air, that she took it to Tyre, and that they worshiped it there in the sacred shrine. We have reason to question whether that Phœnician writer ever lived. What matters it? The existence of the story in Eusebius' time has to us a significance not greatly unlike that of the existence of the worship itself in the earlier years.

Vergil describes a detonating meteor in such terms that I feel reasonably sure that either he had seen and heard, or else he had had direct conversations with others who had seen and heard, a splendid example of these meteors. The passage is in the second book of the Aeneid. The city of Troy was captured and was burning. All was in confusion. The family of Aeneas was gathered ready for flight, but Anchises would not go. An omen, lambent flames on the head of his grandson, began only to shake his purpose to perish with his country. He prayed for more positive guidance. It is Aeneas who describes the scene:

"Hardly had the old man spoken when across the darkness a star ran down from the sky carrying a brilliant light torch. We saw it go sweeping along above the roof of the house. It lighted up the streets and disappeared in the woods on Mount Ida. A long train, a line of light, remained across the sky, and all around the place was a sulphurous smell. A heavy sound of thunder came from the left. Overcome now, my father raised his hands to heaven, addressed the gods and worshiped the sacred star. Now, now, he cried, no longer delay."

This story is, of course, all legendary, but Vergil's description of the scene is true to life as conceived by pagan Rome in his day.

The images that fell down from Jupiter, or that fell from the skies, are often spoken of by Greek and by Latin writers. I mention three or four cases only where this allusion points to a meteoric origin as possible or probable. The earliest representative of Venus at old Paphos on the island of Cyprus, was one of these heaven-descended images. It was not the Venus of the Capitol, nor the Venus of Milo, but as described was a rude triangular stone.

Cicero, in the grand closing passage of his oration against

Verres, calls upon Ceres, whose statue he says was not made by hands but was believed to have fallen from the skies. The earliest of the images of Pallas at Athens was said to have had a like origin. Pausanias saw at Delphi a stone of moderate size which they anointed every day, and covered during every festival with new shorn wool. They are of opinion, he adds respecting this stone, that it was the one given by Cybele to Saturn to swallow as a substitute for the infant Jupiter, which Saturn after swallowing vomited out on the earth.

There is a marvelous story of a peculiar stone in the poem Lithika by the apocryphal Orpheus. Phoebus Apollo gave the stone to the Trojan Helenus, and Helenus used it in soothsaying. It was called Orites, and by some *Siderites*. It had the faculty of speech, and when Helenus wished to consult it he performed special ablutions and fasts for twenty-one days, then made various sacrifices, bathed the stone in a living fountain, dressed it and carried it in his bosom. The stone now became alive, and to make it speak he would take it in his arms and dandle it, when the stone would begin to cry like a child for the breast. Helenus would now question the stone, and receive its answers. By means of these he was able to foretell the ruin of the Trojan state. Whoever framed that story had, I believe, before him a real stone, and the description is very like that of a meteorite, saying nothing of its having come from Apollo. The Orphic writer says that it was rough, rounded, heavy, black, and close-grained. Fibers like wrinkles were drawn in circular forms over the whole surface above and below.

Here I show you a stone such as was described—rounded, black, heavy, close-grained, and having fibers like wrinkles in circular forms over the whole surface above and below.

The name *Siderites* was at a later date applied to the loadstone, but by this writer the two stones are separately described, and are apparently distinct. If this name was of Greek origin it seems to be allied to *sideros*, *iron*, and this heavy stone, like nearly all meteorites, probably contained iron. If, however, this name came from a Latin source (for it is used both by Greek and by Latin writers) it has affinities with *Sidus*, a star, and its meteoric character is still more clearly indicated.

One of the most interesting of the stories about images that have fallen from heaven, is the basis of that beautiful tragedy of Euripides, "Iphigeneia in Tauris." To many of you the story is familiar, but it will bear repetition.

The goddess Diana detained at Aulis the Grecian fleets by contrary winds, and required the sacrifice of Iphigeneia, the daughter of Agamemnon, before the Greeks could set sail. The father consented;—and the daughter, apparently sacri-

ficed, was really rescued by Diana, and borne to the Tauric, or Crimean peninsula on the north shore of the Black Sea. She was then made a priestess in the temple of the goddess. At this shrine the barbaric inhabitants used to sacrifice before an image of Diana, that fell from heaven, all strangers that were shipwrecked upon the coast. The unhappy Iphigeneia, forced to take a leading part in these human sacrifices, laments her sad lot:—

"But now a stranger on this strand,
'Gainst which the wild waves beat,
I hold my dreary, joyless seat,
Far distant from my native land;
Nor nuptial bed is mine, nor child, nor friend.
At Argos now no more I raise
The festal song in Juno's praise;
Nor o'er the loom sweet sounding bend,
As the creative shuttle flies,
Give forms of Titans fierce to rise,
And dreadful with her purple spear
Image Athenian Pallas there.
But on this barbarous shore
Th' unhappy stranger's fate I moan,
The ruthless altar stained with gore,
His deep and dying groan;
And for each tear that weeps his woes,
From me a tear of pity flows."

Orestes, the brother of Iphigeneia, had avenged upon his mother the murder of his father. For this he was driven by the Furies. While stretched before the shrine of Phoebus he heard the divine voice from the golden tripod, commanding him to speed his way to the wild coast of the Taurians, thence to take by fraud or by fortune the statue of Diana that fell from heaven, and carry it to Attica. Doing this he should have rest from the Furies.

He was captured, however, along with his friend Pylades, and brought to the altar to be sacrificed. The relationship of the brother and sister became here revealed, and they together fled, carrying with them the image. It was not without a struggle that they reached the shore, but finally,

"On his left arm sustained
Orestes bore his sister through the tide,
Mounted the bark's tall side and on the deck
Safe placed her and Diana's holy image
Which fell from heaven."

Neptune favored the Greeks, Minerva forbade pursuit, and the image was borne to Halae (or as some said to Brauron) in Attica.

Cicero spoke of the Trojan Palladium as something that fell from the sky;—*quod de coelo delapsum.* Other classical writers, notably Ovid, speak of it in similar terms. The story

in its various forms points toward a stone-fall as its basis. One form of it runs thus :—

Pallas and her foster sister Athena were wrestling with each other, when Pallas was accidentally killed. In grief Athena made an image of Pallas and set it up on Olympus. When King Ilus was about building his city on the Trojan plain he prayed for a favorable omen. In response to his prayer Jupiter cast this image down at the feet of the suppliant king. In the new city it was set up in a temple specially erected to contain and protect it. So long as Troy could keep safely this image, the city, it was firmly believed, could not be taken by its foes.

According to one story the Greeks stole the image before capturing the city. As many cities afterwards claimed to possess the treasure as claimed to be the birthplace of Homer. According to the Romans, Aeneas carried the Palladium to Italy, and the image was regarded as the most sacred treasure of the Roman State. For centuries even in historic times it was so carefully kept by the Vestal Virgins that the Pontifex Maximus was not allowed to see it.

We naturally have doubts about the nature, or even the existence, of an object so kept out of sight. What it was that the Vestals thus guarded, or whether they had anything to represent the image of Pallas, will probably never be known. But it is far otherwise with another famous object of Roman worship. To the east of the Trojan plain on which the Palladium fell rise the mountains of Phrygia and Galatia. In Pessinus, near the border line of these two countries, and in the caves and woods near Pessinus, the goddess Cybele, the mother of the great gods, Jupiter, Neptune, and Pluto, was specially worshiped. This worship may not have been more degrading than the worship of many other Asiatic divinities. But it was wretched and unmanly almost beyond our possible conception. It furnished to Catullus the theme for the most celebrated of his poems, one of the strongest pictures in all literature. The Grecian athlete entered her service with joyful music and dancing. Too late he looks back from the Asiatic shore, out of his hopeless degradation, on the nobleness of his former Grecian life. The lion of Cybele drives him in craven fear again into the wild woods, to spend his days in the menial servitude. The Roman poet exclaims, "O goddess, great goddess Cybele, goddess queen of Dindymus; far from *my* house be all thy frenzies; others, others, drive thou frantic."

At some unknown early time a meteoric stone fell near to Pessinus. It was taken to the shrine of Cybele and there set up and worshiped as her image. This image and its worship

very early attained a wide celebrity. About two hundred years before Christ, in the time of the second Punic war, the stone was transported to Rome. The detailed history of the transfer is given by several writers in varied terms. It forms one of Livy's charming stories, it is told in poetic terms by Ovid, it is given as a tradition by Herodian. For every detail of the history I do not ask confiding belief, but the principal event is, I suppose, historically true.

In the year 205 before Christ Hannibal had, since crossing the Alps, been holding his place in Italy for more than a dozen years, threatening the existence of the Roman State. The fortunes of war were now somewhat adverse to the Carthaginian general. A shower of stones alarmed the Romans. The decemvirs consulted the Sybilline books, and there found certain verses which imported that whensoever a foreign enemy shall have carried war into the land of Italy he may be expelled and conquered if the Idæan mother be brought from Pessinus to Rome. These words were reported to the Senate. Encouraging responses came at the same time from the Pythian oracle at Delphi.

The Senate set about considering how the goddess might be transported to Rome. There was then no alliance with the states of Asia. But King Attalus was on friendly terms with the Romans because they had a common enemy in Philip II. of Macedon. The Senate, therefore, selected an imposing embassy from the noblest Romans. A convoy of five quinqueremes was ordered for them, that they might make an appearance suited to the grandeur of the Roman people. The embassy landed on their way and made inquiry of the oracle at Delphi, and were informed "that they would attain what they were in search of by means of King Attalus, and that when they should have carried the goddess to Rome they were to take care that whoever was the best man in the city should perform the rite of hospitality to her." The king received them kindly, but refused their request, whereupon an earthquake tremor shook the place and the goddess herself spoke from her shrine, "It is my will, Rome is a worthy place for any god; delay not." The king yielded; a thousand axes hewed down the sacred pines, and a thousand hands built the vessel. The completed and painted ship received the stone and bore it to the mouth of the Tiber.

It was the spring of the following year before the ship arrived. Meanwhile new prodigies frightened the people. A brilliant meteor had crossed Italy from east to west, a little south of Rome, and a heavy detonation followed. From this, or from some other meteor, another shower of stones had fallen. In expiation, according to the custom of the country

in case of stonefalls, religious exercises during nine days were ordered. The Senate after careful deliberation selected one of the Scipios, deciding that he of all the good men in the city was the best, and they deputed him to receive the stone. The whole city went out to meet the goddess. Matrons and daughters, senators and knights, the vestals and the common people all joined the throng. But a drought had reduced the water of the Tiber so that the vessel grounded upon the bar. All the efforts of the men pulling upon the ropes failed to move it. A noble matron who had been slandered stepped forward into the water. Dipping her hands three times into the waves and raising them three times to heaven, she besought the goddess to vindicate her good name if she had been unjustly slandered. She laid hold of the rope and the vessel followed her slightest movement, amid the plaudits of the multitude.

Scipio, as he had been ordered by the Senate, waded out into the water, received the stone from the priests, carried it to the land, and delivered it to the principal matrons of the city, a band of whom were in waiting to receive it. They, relieving each other in succession and handing it from one set to another, carried it to the gates of the city, and thence through the streets to the temple of Victory on the Palatine Hill. Censers were placed at the doors of the houses wherever the procession passed, and incense was burned in them, all praying that the goddess would enter the city with good-will and a favorable disposition. The people in crowds carried presents to the temple. A religious feast and an eight days' festival with games were established to be celebrated thereafter each year in the early part of April.

Before another year had passed Hannibal, after having maintained his army in Italy for fifteen years, was forced to withdraw again to Africa. From the liberal offerings of the people, in gratitude for deliverance, a temple was erected to Cybele, long known as the Temple of the Great Mother of the Gods, so that twelve years after its arrival at Rome the stone was taken from the Temple of Victory and set up in its new home. A silver statue of the goddess was constructed, to which the stone was made to serve in place of a head. Here, in public view, for at least five hundred years that stone was a prominent object of Roman worship. Its physical appearance is described by several writers. It was conical in shape, ending in a point, this shape giving occasion to the name *Needle of Cybele*. It was brown in color, and looked like a piece of lava. Arnobius, a Christian writer just before the accession of Constantine, and over five hundred years from the date of its arrival at Rome, says of the stone:

"If historians speak the truth and insert no false accounts

into their records, there was brought from Phrygia, sent by King Attalus, nothing else in fact than a kind of stone, not a large one, one that could be carried in a man's hand without strain, in color tawny and black, having prominent, irregular, angular points, a stone which we all see to-day, having a rough irregular place as the sign of a mouth, and having no prominence corresponding to the face of an image." Arnobius goes on to ask whether it was possible that this stone drove the strong enemy Hannibal out of Italy,—made him who shook the Roman State, unlike himself, a craven and a coward.

Just when this stone disappeared from public view I do not know. In directing the recent excavations on the Palatine Hill, Prof. Lanciani was at first in great hopes of finding it;—because it had no intrinsic value to the many spoliators of Rome, nor to the former excavators of Roman temples. But the place in which he expected to find it was absolutely empty. At a later date, however, he found in a rare volume an account of excavations made on the Palatine Hill in 1730, in which the private chapel of the Empress was found and explored. In this we perhaps have an account, and it is to be feared, the last account of a sight of the Cybele stone. The writer says: "I am sorry that no fragment of a statue, or bas-relief, or inscription has been found in the chapel, because this absence of any positive indication prevents us from ascertaining the name of the divinity to whom the place was principally dedicated. The only object which I discovered in it was a stone nearly three feet high, conical in shape, of a deep brown color, looking very much like a piece of lava, and ending in a sharp point. No attention was paid to it, and I know not what became of it." This description is almost identical with that given by Arnobius and others of the stone from Pessinus.

Another stone of meteoric origin was brought to Rome, and there for a brief period was most fantastically worshiped. This was near the beginning of the third century after Christ. It came like the other stones of which I have spoken from Asia. In the City of Emesa, on the banks of the Orontes about midway between Damascus and Antioch, there was in those days a magnificent temple of the Sun. A gorgeous worship was maintained before a stone that fell from heaven, that served as the image of the Sun-god. The description of it is not very unlike that of the Cybele meteorite. Herodian, who probably saw it, says: "It is a large stone, rounded on the base, and gradually tapering upward to a sharp point; it is shaped like a cone. Its color is black, and there is a sacred tradition that it fell from heaven. They show certain small prominences and depressions in the stone, and those who see them persuade their eyes that they are seeing an image of the sun not made by hands."

This Sun-god was named Heliogabalus, and before the altar a boy of nine years of age began to serve as priest. Such a Syrian service did not make the boy grow manly nor virtuous, and when at the age of fifteen he became emperor through the money and intrigues of his grandmother, and the murder of the Emperor Macrinus, we have for three years at Rome the view of the sorriest scrapegrace that ever sat on a throne. He assumed with the name of Antoninus also the name of his god Heliogabalus. To the great disgust of the Roman Senate and people, he brought with him from Syria the image of his god, the sacred stone, and himself continued before it his priestly service with all its fantastic forms and gesticulations. He built within the city walls a grand and beautiful temple, with a great number of altars around it; he repaired thither every morning, and sacrificed hecatombs of bulls and an infinite number of sheep, loading the altars with aromatics, and pouring out firkins of the oldest and richest wines. He himself led the choruses, and women of his own country danced with him in circles around the altars, while the whole Senatorian and Equestrian orders stood in a ring like the audience of a theater.

But now he must have a wife for his god. So he broke into the apartments guarded by the vestals and carried to the palace the Trojan Palladium, or what he supposed was that object, and was intending to celebrate the nuptials of the two images. His god, however, he concluded would not be pleased with a warlike wife like Pallas, therefore, he ordered brought from Carthage an ancient image of Urania, or the Moon, which had been set up by Dido when she first built old Carthage. With this image he demanded the immense treasures in her temple, and he also collected from every direction immense sums of money to furnish to the Moon a suitable marriage portion when married to the Sun.

He built another temple in the suburbs of Rome, to which the Emesa stone, the god (?) was carried in procession every year, while the populace were entertained with games, and shows, and feastings and carousings. Herodian thus describes this performance:

"The god was brought from the city to this place in a chariot glittering with gold and precious stones, and drawn by six large white horses without the least spot, superbly harnessed with gold and other curious trappings reflecting a variety of colors. Antoninus himself held the reins—nor was any mortal permitted to be in the chariot; but all kept attendant around him as charioteer to the deity, while he ran backward leading the horses, with his face to the chariot, that he might have a constant view of his god. In this manner he performed

the whole procession, running backwards with the reins in his hands, and always keeping his eyes on the god, and that he might not stumble or slip (as he could not see where he went), the whole way was strewn with golden sand, and his guards ran with him and supported him on either side. The people attended the solemnity, running on each side of the way with tapers and flambeaux, and throwing down garlands and flowers as they passed. All the effigies of the other gods, the most costly ornaments and gifts of the temples, and the brilliant arms and ensigns of the imperial dignity, with all the rich furniture of the palace, helped to grace the procession. The horse and all the rest of the army marched in pomp before and after the chariot."

The reign of a foolish boy at this period of Rome's history was necessarily a short one, and at the age of eighteen the soldiers killed him and let the Roman populace have the body to drag through the city streets. The worship of the Sun-god at once ceased, and, no doubt, the stone also was thrown away. The Cybele stone, however, remained an object of public worship, since the quotation from Arnobius, which I have given, was written nearly a century later than the reign of Heligabalus.

I propose to speak briefly of one more meteorite whose worship has had a world-wide fame;—the image of the Ephesian Artemis. This worship had its center at Ephesus, but was widely extended along the shores of the Mediterranean. Temple after temple was built on the same site at Ephesus, each superior to the preceding, until the structure was reckoned one of the seven wonders of the world. As a temple, it became the theatre of a most elaborate religious ceremonial. As an asylum, it protected from pursuit and arrest all kinds of fugitives from justice or vengeance. As a museum, it possessed some of the finest products of Greek art, notably works of Phidias and Apelles. As a bank, it received and guarded the treasures which merchants and princes from all lands brought for safe keeping. In its own right it possessed extensive lands and large revenues. The great City of Ephesus assumed as her leading title that of *νεωκόρος*, or temple-warden of Artemis, putting this name on her coins, and in her monumental inscriptions.

The image, which was the central object in this temple, was said to have fallen from heaven. Copies of it in all sizes and forms were made of gold, of silver, of bronze, of stone and of wood, by Ephesian artificers, and were supplied by them to markets in all lands. What a lifelike picture is given us in the 19th chapter of the Acts of the Apostles, of the excited crowd of Ephesians, urged on by the silversmiths, who made for sale

the silver shrines of the goddess, and who saw that their craft was in danger if men learned to regard Artemis as no real divinity, and to despise the image that fell down from the sky.

We cannot suppose that the Ephesian Artemis image of the first century was a meteorite, though we have the distinct appellation, Diipetes, fallen from the sky. But I believe that there was a meteoric stone that was the original of the Ephesian images, and it seems not at all improbable that in some one of the destructions of the temple it disappeared. Or, in the progress of time, there may have been a desire to represent the goddess in a more artistic form than the shapeless stone afforded.

Many forms of the Ephesian Artemis are still preserved, and they have, amid all their variations, a certain peculiar character in common. That common character seems to me to confirm the statement that the original image fell from heaven. This goddess is regarded, let me say, as different from the Grecian Artemis, the beautiful huntress so well known in Greek art, and I am speaking only of the images of the Ephesian Artemis.

There is one peculiarity in the outward forms of the meteorites that is characteristic of nearly all of them. I mean the molded forms, and the depressions all over the surfaces. They are better appreciated by being seen, than by any description I can give you. They are common to meteorites of all kinds, from the most friable stone to the most compact iron. (I show you one, a stone from Iowa—also the plaster cast of another, a stone from some fall, I know not which one.) Those who have recently visited the collection in the Peabody Museum may recollect the model of an iron that fell two or three years ago in Arkansas, which displays most beautifully these depressions.

Let now an artist attempt to idealise any one of these molded forms, and to make something like a human shape out of one of them. He must necessarily set it upright, and he must give it a head. You have then a head surmounting one of these molded forms. Let now the convenience and the taste of the artificers of the images have some liberty to act—and we know that they did act, for we have considerable variety in these images—and a development in the conventional representation of the image is sure to follow.

[The lecture closed with the exhibition of a series of lantern pictures showing the forms of some typical meteorites.]

Art. II.—*The Spectra of Argon;* by John Trowbridge and Theodore William Richards.

It is well known that argon possesses at least two marked spectra—one, termed the red, which is chiefly characterized by red lines; and another called the blue, which, as its name signifies, is strongly marked by blue lines.

In studying these spectra by means of a high tension accumulator, we have been led to observe carefully the electrical conditions necessary for producing them. It is obvious that a battery of a large number of cells is the most suitable source for the study of discharges of electricity through gases. Especially is this true of a storage battery; for the readiness with which it can be charged by a dynamo, the constancy of the electromotive force (about 2·1 volts per cell), the ease with which it can be coupled for quantity or tension; and the steadiness of the discharge afforded by it, make such a battery far superior to an induction coil or to an electrical machine.

With an induction coil the discharge is not undirectional and is affected by the necessary irregularities of the break. These irregularities make themselves felt in a marked degree when a condenser is used in the secondary circuit. The electrical machine gives an intermittent current, and has a varying capacity. The advantages of a battery for the study of the discharge of electricity through gases have been pointed out by De la Rue and Miller and by Hittorf.* These investigators worked with voltaic cells which were not constant and which required great oversight and continual renewals. In our investigations we are using a lead accumulator of the Planté type; and we find it highly advantageous for spectroscopic work; for by means of the steady current afforded by it, one can study the spectra of gases under especially good conditions.

Our battery consists of five thousand cells, so arranged that they may be disconnected and wholly reconnected in any desired manner in less than a minute. The electromotive force of the complete series is somewhat over ten thousand volts, but when the cells are connected for quantity, they may be readily charged by means of a dynamo giving a tension of only sixty volts. The insulation of the terminals of this battery was a matter of some difficulty, for even dry wood allows considerable leakage from one case of cells to another; but by the plentiful use of paraffin, mica, and vulcanite, the problem was solved with reasonable success. The discharge from only a very small fraction of the battery produced a most uncom-

* Ann. der Phys. und Chem. (N. F.), vol. vii, 1879, p. 553.

fortable shock, and it is probable that the discharge of the whole battery would be instantly fatal. The great heat of this full discharge immediately shatters a Geissler tube, the glass being splintered throughout the whole length of the capillary. Hence a resistance of several million ohms was usually interposed between the battery and the rest of the apparatus. This resistance was also of service in protecting the experimenters from serious accidental shocks. Ordinary distilled water contained in long tubes with movable electrodes was the most convenient resistance for our purpose; dilute solutions of cadmic iodide in amyl alcohol and of cadmic sulphate in water between cadmium electrodes, were also sometimes used. Unless these liquids are contained in tubes of rather large diameter, they are likely to cause irregularities by boiling under the influence of the heat of the current. Graphite resistances are too combustible for the purpose.

The argon used in our experiments was very kindly given to one of us by Lord Rayleigh. It was a portion of the purest preparation which had been used in his final determinations of the density of the gas; and our tubes were carefully filled with it by the kindness of F. O. R. Götze, of Leipzig. The preliminary work described in this paper was chiefly done with a single tube containing gas at a pressure of about 1^{mm}. The tube had a wide capillary and was about 15^{cm} in total length. In such a tube, the red glow of argon is readily obtained with a voltage of about two thousand, but not with much less. A higher tension of gas demands a higher tension of electricity in order to start the discharge, no matter how much or how little other resistance is interposed; but when the glow has once started it is continued by means of a much smaller electromotive force. This is shown by the fact that a Thomson electrostatic voltmeter, connected with the terminals of the Geissler tube, indicated differences of potential between the ends of the tube ranging from six hundred and thirty volts upward. De la Rue and Miller, who found no potential difference between the ends of Geissler tubes, must have been working with discontinuous discharges. Crookes's estimate that 27,600 volts are necessary to produce the red spectrum is evidently excessive.

The introduction of a capacity between the terminals of the Geissler tube, for example, two plates of metal sixteen hundred square centimeters in area separated by plate glass one centimeter thick, made no difference in the red glow, so long as the connections were good and the condenser quiet.* As soon as a spark gap was introduced, or the condenser began to

* Sir W. Thomson (Lord Kelvin): Papers on Electrostatics and Magnetism. MacMillan, 1872, p. 236.

emit the humming sound peculiar to it, the beautiful blue glow so characteristic of argon immediately appeared.

If this light is examined by a revolving mirror it is seen to consist of intermittent discharges. The battery charges the condenser to the potential necessary to produce a spark between the terminal of the spark gap. The discharge of this accumulated electricity is produced in the tube and then the operation is repeated. The time interval between the discharges is evidently a function of the capacity of the condenser, as well as of the electromotive force of the battery and the resistance between it and the condenser.

The accurate determinations of the potential and current strength of the intermittent blue discharge is a matter of some difficulty: and at present we feel hardly in position to make a definite statement regarding these measurements. However, the potential required certainly cannot be greater than two thousand volts,—the electromotive force of the battery which will easily produce the blue glow. Here again, Crookes's estimate of far above 27,000 volts was very much too large.

Since it is necessary to employ a condenser to produce the blue spectrum of argon, we were led to examine the electrical conditions which are necessary for the discharge. In the circuit with the tube containing argon, between the tube and one of the plates of the condenser, we first interposed a small coil of about eight ohms resistance, having a self-induction of ·015 of a henry. The blue glow changed to the red glow. We then modified the self-induction and discovered that even the self-induction of the leads to the tube, which consisted of a few feet of uncoiled wire, undoubtedly modified the blue discharge, for an amount of induction equivalent to ·000051 henry had a marked effect in diminishing the brilliancy of the blue glow.

A comparatively small ohmic resistance substituted for the impedance of the self-induction between the tube and one plate of the condenser produced precisely the same effect as this coil, causing a complete transformation from blue to red. The change from blue to red is so marked that a tube of argon may well serve as an inductometer of some sensitiveness, as well as a means of comparing the influence of self-induction with ohmic resistance. The effect of impedance or resistance must be to prolong or to damp the oscillations of the condenser discharge. Indeed, the resistance of the tube itself may be so great as to damp the oscillations without the need of the introduction of outside resistance or self-induction; therefore argon at high tension gives the red glow with a condenser and rate of oscillations which are quite capable of producing the blue glow in a tube of lower tension.

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Kayser* criticises Crookes's statement that a condenser and a spark gap are necessary for the production of the blue spectrum. He finds that with a lower pressure in the tube than 2^{mm} the blue spectrum can be readily obtained without condensers and spark gaps. He also states that it is much easier to produce the pure blue spectrum than the pure red. In order to obtain the red spectrum the strength of the current must be adapted to the gas pressure. Kayser employed an induction coil. The condenser, however, in the primary of an induction coil sends an oscillatory discharge through the secondary. Although Kayser did not employ a condenser in the manner recommended by Crookes, he still had a condenser in his electrical system and the resistance of his Geissler tube was probably so proportioned that the secondary circuit was in resonance with the primary circuit. To prove this we placed a tube containing argon across the terminals of the secondary of an induction coil, and having removed the condenser attached to the primary, we sent the discharge through the tube by means of a break in the induction coil. The light of the discharge was red, and when it was examined by a revolving mirror no trace of blue was seen in the capillary portion of the tube. An adjustable condenser and a variable induction were then placed in the primary circuit. By varying the amount of the capacity together with the self-induction in the primary system, the discharge in the secondary, when examined by a revolving mirror, was seen to consist of both red and blue discharges. The red glow was evidently due to a unidirectional discharge and the blue to an oscillatory discharge. The unidirectional discharge was caused by the failure of the breaks to charge the condenser to the primary, or by increased resistance in the tube. When, however, the condenser was charged, it immediately discharged in an oscillatory manner; and the secondary coil responded by resonance. The rarified argon thus shows in an interesting manner what is the function of the condenser in the primary of an induction coil. It serves to send oscillatory discharges through the primary circuit; and the greatest effect is obtained in the secondary circuit when it is in resonance or in tune, so to speak, with the primary.

The presence of a condenser was necessary to form the blue glow in Kayser's work, only when the resistance of his tube and the self-induction of his coil together were enough to damp the discharge of the small capacity of the coil. He could have obtained the pure red in any case by interposing, as we have done, a resistance or self-induction between the condenser and the tube, although our other resource for obtaining

* Sitzungsberichte der königlich preussischen Akad. der Wissenschaften zu Berlin, May 7, 1896.

the red glow in any tube from the continuous discharge of a constant battery was apparently not open to him.

By taking out all resistances except the spectrum tube, and sending an exceedingly strong current through the tube for very brief intervals of time, we have been able to cause the blue glow; but it seems probable that under these conditions the capacity of the battery itself engenders oscillations which are no longer damped by interposed resistance. Whether the blue glow with its accompanying change of spectrum is due merely to the great quantity of electricity discharged in a very short space of time, or to some property intrinsic in the to-and-fro motion of the oscillatory discharge, is a question, which we hope soon to answer. The red glow, if caused by oscillations at all, must be caused by oscillations within the Geissler tube itself;* for all outside oscillations are cut off by the large resistance between the battery and the tube.

The effect of the oscillatory discharge in producing the blue spectrum of argon can also be shown by the use of an electrical machine. If the terminals of the tube containing argon are connected with the terminals of an electrical machine, the pure red spectrum is obtained. If a spark gap is interposed in such a manner that a condenser charged by the machine can discharge through the tube, the blue discharge immediately results. The condenser discharge oscillates through the gas.

The oscillatory discharge of the condenser is evidently an important factor in producing the blue spectrum of argon. According to Lord Kelvin's law, if R denotes the resistance of the circuit, L, the self-induction, and C the capacity of the circuit, the discharge of the condenser becomes non-oscillatory when $R = \sqrt{\frac{4L}{C}}$. It may be, therefore, that an estimate of the resistance in the tube can be obtained by measuring the self-induction which is required to change from the blue discharge to the red.

When the tube containing argon at a suitable pressure is brought near a Hertz oscillator, giving a rate of about 115,000,000 oscillations per second, it immediately shows the blue color. In this case the oscillator consisted of two zinc plates about 40^{cm} square with a spark gap between them. The capacity and impedance of the circuit was extremely small.

The unusual sensitiveness of an argon tube to oscillatory discharges leads us to believe that it will be of great use in the study of wave motions of electricity. As we have seen, it is competent to show when the Hertz oscillator is working properly, that is, sending forth electrical oscillations and not unidi-

* Ann. der Physik und Chemie, 1893, vol. xlviii, 549, Ebert and E. Wiedemann.

rectional discharges. The change of color in the tube from red to blue is so marked that an argon tube reveals what is not shown in a conspicuous manner by other gases. We have thought that this remarkable property of an argon tube is worthy of being distinguished by a name which might describe it and we have, therefore, called an argon tube fitted for the study of electrical waves a talantoscope (*ταλάντωσις*).

In an oscillatory discharge the molecules receive powerful electrical impulses of opposite sign. These impulses are separated, it may be, by millionths of a second. It is significant that the shorter wave lengths of light accompany these electrical oscillations. It is our purpose to extend our study of the effect of electrical oscillations through more highly rarified media in which arise the Röntgen rays. These rays are probably highly modified by the oscillatory discharge. A battery of a large number of cells now at our command will afford the best means of studying this subject: for its discharges, as we have pointed out, are free from the fluctuating effects produced by induction coils, transformers and electrical machines. Our present paper is, therefore, only preliminary to a more exhaustive study of the discharges of electricity through rarified gases, by means of a storage battery of ten thousand cells, which will give an electromotive force of about twenty thousand volts.

Harvard University, Dec. 1st, 1896.

ART. III.—*Some Queries on Rock Differentiation;* by GEO. F. BECKER.

Hypothesis of differentiation.—As I understand the theory of what is called the differentiation of rock magmas, now so generally held by lithologists, its outlines may be expressed in the following terms: In some extensive districts the massive rocks are found to possess similarities of composition, and such rocks have been called consanguineous. This consanguinity might be accounted for by supposing an originally homogeneous magma to have undergone partial segregation into fluid portions of distinctly different yet allied composition, prior to eruption, and this is the process called differentiation. It is also known by observation in the laboratory, that if a more or less complex, homogeneous solution be exposed to certain physical conditions, segregation into distinct portions may take place. It is hence inferred that such is actually the history of consanguineous rocks.* By a slight extension of this inference most massive rocks are regarded as resulting by differentiation from a generalized magma.

The existence of distinct though allied rocks locally associated with transitional varieties is undisputed. The validity of the explanation offered by the modern school for these occurrences is another matter. The hypothesis of differentiation is extremely attractive and if it were substantiated would lead to a well organized system of rock investigation. It may also be correct; but there are respects in which it appears to be in need of much explanation, and it does not seem certain that the fundamental postulate of originally homogeneous magmas of vast volume is well established.

Possible modes of segregation.—The segregation† of a homogeneous fluid into distinguishable portions under the influence of varying temperature or pressure may take place by different methods. An increase or decrease in the concentration of certain components may occur in the cooler part of the fluid or in that portion which is under greatest pressure. There are also cases in which solutions which are homogeneous

* The early literature bearing on this subject, together with fresh contributions, is given in Mr. Arnold Hague's work on the Geology of the Eureka district, U. S. Geol. Survey, Mon. 20, 1892, p. 267 et seq. Some of Prof. J. P. Iddings' papers bearing on the subject are: the Crystallization of Igneous Rocks, 1889; Electric peak and Sepulchre mountain, 1891; the Origin of Igneous Rocks, 1892, etc. The latest of Prof. W. C. Brögger's contributions is: die Eruptionsfolge der triadischen Eruptivgesteine bei Predazzo, 1895.

† The term differentiation is ambiguous. In the older, and as it seems to me the more proper sense, differentiation is the discrimination of existing differences. One differentiates lime-soda feldspars by their angles of extinction.

at one temperature tend to separate at some other temperature into two or more immiscible fluids, or into a fluid portion and a solid one. There seem to be no other conceivable ways in which segregation or differentiation under purely physical influences can take place, and it is one of the purposes of this paper to examine the mechanism of these processes in the light of the modern conclusions of chemical physics.

It will be most convenient to consider first those cases in which only miscible liquids, or liquids present only in miscible proportions, are concerned, reserving consideration of immiscibility and insolubility for subsequent discussion.

The differentiation of a homogeneous magma, or its segregation into distinct though related miscible fluids, involves relative movement of the particles of the magma. This movement cannot take place in visible streams or currents, such as would result from convection; for if a tendency to segregation existed, stirring would neutralize or overcome it. Segregation might, however, be accomplished by what may be called *molecular flow*, this term being understood to mean the progressive translation of portions of a liquid, molecule by molecule, among the similar or dissimilar molecules of the remainder of the liquid.

Instances of molecular flow.—Molecular flow is exhibited in ordinary diffusion, in osmosis, and in some cases of the segregation of fluids. Although these are seemingly very different manifestations, they are all reducible to the tendency which fluids exhibit to attain a condition of stable equilibrium, through an equalization of the partial pressures of each component in different parts of the fluid.

If two liquids which are miscible in all proportions but are chemically indifferent to one another are placed in a small closed vessel and are maintained at a constant temperature, each diffuses into the other, and the flow of molecules will never cease until the mixture is uniform throughout, so that each liquid occupies the volume formerly occupied by both. If two such liquids are each soluble in a third, each will diffuse into the solvent at its own peculiar rate, and in such cases mere diffusion produces partial separation of the dissolved substances. At any given time the substance which diffuses more rapidly will be found in greater relative abundance at any point at all distant from the original surface of diffusion. Thus Graham in experimenting on the diffusion in water of a solution which contained 5 per cent of common salt and 5 per cent of sodium sulphate found that the upper layer of water after a certain interval contained ten times as much of the chloride as of the sulphate.

In this case any one layer of the water may be regarded as a kind of septum through which the chloride diffuses at a higher rate than does the sulphate. There are many septa more efficient in separating solutions than is water. Especially familiar is bladder, through which one class of compounds (the crystalloids) passes very readily, while another (the colloids) passes with difficulty. Here indeed the material of the septum perhaps has some molecular action on the solutions, and if so the explanation is thereby complicated. Nevertheless osmosis is regarded by physicists as a case of ordinary diffusion complicated, as some think, by the molecular action of the septum.*

There is another class of septa which seems to be without molecular action and behave as mere "atomic sieves." They are wholly impermeable to some solutions (bladder is not) and easily permeated by others. By means of these "semi-permeable" septa, which are produced by precipitation, it has been found that the molecular flow of a given solution continues until a certain definite pressure exists on one side of the septum, this pressure being characteristic of the substance experimented upon and independent of the nature of the membrane. This is the "osmotic" pressure of the dissolved substance, and Mr. van't Hoff has shown† that it is equal to the pressure which would be exerted by the substance in a gaseous state when occupying the same volume at the same temperature. Evidently then there is a very close analogy between gases and substances in a state of solution, and it is in fact now well recognized that, as van't Hoff pointed out, they obey several of the same fundamental laws when osmotic pressure and simple pressure are considered as interchangeable terms.‡

Mr. W. Nernst§ has discussed the phenomena of simple diffusion in their relation to osmotic pressure and is led to the conclusion that osmotic pressure is the force immediately concerned in the diffusion of liquids, just as the pressure exerted by a gas in confinement is the cause of the diffusion of gases.

The most important case of molecular flow for the purposes of this discussion arises when a homogeneous solution is heated at the top. Molecular flow then takes place from the top

* Tait: Prop. of Matter, 2d ed, p. 275. It is probable that the osmotic action of animal membranes is exactly the same in principle as that of precipitated ones. They are both "atom sieves," only the "meshes" are of a different size, perhaps. If any "molecular action" (whatever that may be) exists in one case, it probably does in the other also. The evidence of such action is not distinct.

† Zeitschr. phys. Chem., vol. i, 1887, p. 481.

‡ The osmotic pressure is inversely proportional to the volume of the fluid in a given space. The osmotic pressure at constant volume is proportional to the absolute temperature. Solutions of equal volume of different substances which contain equal numbers of molecules at equal temperatures exert equal osmotic pressure. These laws correspond to those of Boyle, Gay-Lussac and Avogadro.

§ Zeitschr. phys. Chem., vol. ii, 1888, p. 613.

towards the bottom, so that a concentration of the substance in solution occurs in the lower portion. This fact appears to have been observed first by Mr. C. Ludwig in 1856* and was subsequently studied by Mr. Ch. Soret.† The phenomenon has been explained by Mr. van't Hoff.‡ The osmotic pressure of a substance in solution is proportional to the absolute temperature. Hence there is a resultant pressure in an unequally heated fluid which is directed towards the cooler portion, and this will not be equilibrated until the osmotic pressure in the cooler portion is appropriately increased. Now the osmotic pressure is proportional to the concentration as well as to the temperature; and the condition of equilibrium is therefore that the concentrations should be inversely as the absolute temperatures. Thus if a magma were heated to $T = 1500°$ at the top while the bottom of the mass were kept at $T = 1400°$, the concentration of the substances dissolved in the magma would increase until that at the bottom were $15/14 = 1{\cdot}07$ of that at the top. Mr. van't Hoff's theory of this case agrees somewhat roughly but substantially with Mr. Soret's experiments.

The solution of any substance in a fluid is attended by a change in the total volume. When this change is a decrease in volume, solubility increases with increasing pressure; and vice versa. Hence in a deep mass of solution of constant temperature there is believed to be a tendency to concentration through pressure at the bottom or the top of the mass. The change of concentration, however, would be so small that physicists are not hopeful of demonstrating it experimentally. The thermodynamical discussion of Messrs. Gouy and Chaperon§ seems to show that even in vessels 100 meters in depth the effect of gravity on sodium chloride solution would influence concentration only to the extent of a fraction of 1 per cent, the concentration being greater at the bottom. It is evident that the process by which concentration is effected is molecular flow. Further remarks on the variability of solubility with pressure will be made in discussing the properties of immiscible fluids.

There is no question that molecular flow does play a part in lithogenesis. One may often see blebs or smears of matter in either granular or porphyritic rocks which have manifestly undergone at least superficial solution, the rock around the bleb showing an aureole of diffusion. So, too, crystallization in many cases is explicable only by the molecular flow of a cer-

* Wien Sitz. Ber., vol. xx, 1856, p. 539.
† Comptes Rendus, Paris, vol. xci, 1880, p. 289.
‡ Zeitschr. phys. Chem., vol. i, 1887, p. 487.
§ Ann. de ch. phys. (VI), vol. xii, 1887, p. 384.

tain ingredient to one spot from the adjacent mass. There is absolutely no theoretical reason why such processes should not occur, for at very short distances molecular flow is a very rapid process, as will be explained presently. On the other hand, it is questionable whether masses of rock of hundreds of meters in thickness could be thus separated, even if the time allowed for completion of the process were equal to an entire geological period.

Character of diffusion.—It has been explained above that all the processes of molecular flow are reducible to the same elementary action, viz: movements due to differences of osmotic pressure. This kind of flow is most simply manifested in ordinary diffusion, and it is also in the ordinary diffusion of concentrated solutions that molecular flow takes place most rapidly. It is possible to bring an indefinitely large mass of an absolutely and permanently concentrated liquid in contact with another liquid in which the first is thoroughly soluble. Under these conditions, the resultant osmotic pressure being proportional to concentration, must have its highest value, and molecular flow (measured by the amount of substance passing through a given area in a given time) must be greater than it otherwise can be. Think, for example, of a tall vessel at the bottom of which is a layer of solid sulphate of copper, the rest of the vessel being full of pure water. Then a concentrated solution of the sulphate will form in contact with the solid sulphate and this layer will continue concentrated until solution is complete. Diffusion will then proceed as rapidly as it can do at the temperature of the experiment. Under such conditions the amount of a dissolved substance which diffuses through an area of one square centimeter in one second, when the gradient of concentration (perpendicular to the area) is one gram of substance per cubic centimeter of fluid per centimeter of distance, is a constant called the "diffusivity" of the substance in water.* In the case of gases Maxwell showed that a simple numerical relation exists between the diffusivity of substance, the diffusivity of energy or heat, and the diffusivity of momentum which gives rise to viscosity.† In the case of fluids the *a priori* determination of these constants is not yet possible and they must be found by experiment.

When this constant called diffusivity of substance is determined, the process of diffusion can be accurately predicted under uniform conditions of temperature and pressure at least for weak solutions. In 1855 Prof. A. Fick‡ advanced the hypothesis that the time rate at which a salt diffuses through a

* Tait: Prop. of Matter, 2d ed., 1890, p. 271.
† Theory of Heat, 1894, p. 332, and Nature, vol. viii.
‡ Pogg. Ann., vol. xciv, 1855, p. 59.

stated area is proportional to the difference between the concentrations of two areas infinitely near one another. This is, *mutatis mutandis*, the same law which underlies Fourier's treatment of heat conduction.* Very extended researches by many physicists have confirmed Fick's law, excepting for very strong solutions, and therefore also the applicability of Fourier's mathematical developments concerning conduction to the elucidation of diffusion. It can be shown that Fick's hypothesis would be strictly applicable to solutions of any concentration if Pfeffer's law, that osmotic pressure and concentration are proportional, were exact. But this law corresponds to Boyle's law that gaseous pressure and volume are inversely proportional, and this, as every one knows, is exact only when the number of molecules per unit volume is not too great. At least two influences tend to render Pfeffer's law and Fick's hypothesis inexact for high concentration. There is a tendency to change of molecular weight with increasing concentration, a species of polymerization, and this would be attended by decreased diffusibility. When there is no such aggregation there is an increase of diffusibility, due, it is thought, to the attraction between the solvent and the dissolved substance.

While it is proper to point out the deviation of very strong solutions undergoing diffusion from the law of Fick, this deviation is of importance only near the contact from which diffusion takes place, and not always then. For if a solvent dissolves a salt only to a limited extent, even a saturated solution may be a weak one, and dissolved molecules will not be so crowded as to show irregular behavior. Thus in the case of magmas undergoing molecular flow, Fick's law will be valid at least to within a short distance from contacts and may hold absolutely up to the contact. In the differentiation of a homogeneous magma into consanguineous portions it is hardly supposable that the molecules undergoing transfer are densely crowded. Consanguineous rocks do not differ very greatly in composition, so that no extensive transfer of material is called for. Furthermore, magmas must be regarded as solutions of a series of very similar substances, and it is known that in such cases the solubility of each is diminished by the presence of the others. This was first pointed out by Mr. Nernst and has been confirmed on experimental and theoretical grounds by Dr.

* If v is the quantity of substance in solution per unit volume in Fick's case (or the temperature in Fourier's), if x is the distance measured in the single direction in which diffusion is supposed to take place, and if κ is the diffusivity regarded as constant, then in either problem

$$\frac{dv}{dt} = \kappa \frac{d^2v}{dx^2}.$$

A. A. Noyes.* Thus the solubility of lead chloride is reduced by the presence of other chlorides to something like one-half of its separate solubility. It appears substantially certain therefore that a series of silicates in solution must restrict the solubility of each. Consequently conclusions drawn from the assumption that Fick's hypothesis is exact will be applicable to the process of differentiation.

It is interesting and extremely important to observe that the problem of determining the distribution of a diffusing lava is formally the same as that of finding the distribution of temperature in a cooling globe of large radius. This last is a subject which has become familiar to geologists through Lord Kelvin's application of the results in estimating the age of the earth.

The diffusivity of a substance is inversely proportional to the molecular friction which the molecules or the ions experience. Thus if r_1 and r_2 are the frictional resistances of the ions of an electrolyte, O the osmotic pressure and D the diffusivity, then, as was shown by Nernst:

$$D = \frac{O}{r_1 + r_2}$$

This internal friction is usually known in English as viscosity. The viscosity of liquids so far as is known increases with the pressure to which they are subjected, with the exception of water, which at ordinary temperatures becomes less viscous with increasing pressure. Of course water at temperatures approaching its freezing point is an anomalous liquid. According to Amagat, the anomalous expansion of water ceases at 50° C. and Tammann suggests that the exceptional relation between viscosity and pressure is probably confined to the same limit.

Rate of diffusion.—If two miscible solutions are brought in contact and a time t, measured in seconds, is allowed to elapse, the fluid at a distance of x centimeters from the contact will contain a certain amount of the diffusing fluid per cubic centimeter, which may be called s. One of the fluids may be supposed kept at constant composition, as in the case of a solid dissolving in a solvent. Then this same concentration s will be found at nx centimeters after the lapse of n^2t seconds. For example, if common salt is brought in contact with water, the water in immediate contact with the salt will soon become saturated. At the distance of 1^{cm} the solution will be half saturated in about one day; at 2^{cm} it will be semi-saturated in four days and at 100^{cm} in $100^2 = 10{,}000$ days; at 100 meters the

* Zeitsch. phys. Chemie, vol. ix, 1892, p. 623.

water would contain half as much salt as it could dissolve after 10,000×10,000 days, some 270,000 years.

It is because of these relations that stirring is so efficaceous in assisting solution. If a mass of fluid consisting of equal but separate parts of concentrated brine and water were so stirred that the streaks of each were not more than a couple of centimeters in thickness, a day would complete by diffusion a homogeneity which unassisted diffusion could accomplish only after hundreds of thousands of years.

Now salt (in common with other haloids) is a highly diffusive substance. The oxygen salts, such as the sulphates of zinc, copper and magnesium, are more analogous to the silicates which compose magmas. Of these the magnesian salt diffuses fastest and the zinc salt the slowest. As an illustration, the copper salt may be taken. Its diffusivity has been determined by Mr. T. Schuhmeister at 0·00000243 in square centimeters per second. With this datum it is easy to compute the distribution of the diffusing salt at any time.* The following table is computed for one year and for 1000 years from the commencement of diffusion. The distances are measured in centimeters from the contact, and under "saturation" the quantity of sulphate of copper per unit volume of the substance at corresponding distance is given, the strength of the original undiffused sulphate solution being taken as unity:

Saturation.	Distance in centimeters; time 1 year.	Distance in meters; time 1000 years.
1·000	0·	0.
·750	3·96^{cm}	1·25^{m}
·500	8·36	2·77
·250	14·24	4·50
·100	20·37	6·44
·050	24·45	7·73
·025	27·76	8·78
·010	31·91	10·19
·005	35 04	11·08

Diffusion of $CuSO_4$ at the end of 1 year and of 1000 years [or of hypothetical lava at the end of 50 times these periods; or of heat in underground strata after $2^h\ 8^m$ and of 89 days].

The last number in this table shows only half of 1 per cent of the original solution and this may be taken as the limit of sensible diffusion. It is easy to derive from this table the figures for any other time. Thus after a hundred years the distances answering to the given saturations will be ten times as great; sensible diffusion will cease at 350^{cm} and semi-saturation

* For the necessary information on this computation see Kelvin's Math. and Phys. Papers, vol. iii, p. 432, or Brit. Assoc. Rep., 1888.

will occur at 84^{cm} from the original contact. After 10,000 years the distances just stated will each be multiplied by 10. At the expiration of a million years the water would be just sensibly discolored by bluestone at 350^{m} and semi-saturation would have reached to a distance of some 84^{m}.

Viscosity of lavas.—Lavas are assuredly far less diffusible and far more viscous substances than sulphate of copper solution.* There is no means of determining with any approach to accuracy what the diffusivity of lava really is, but there is some reason to think that the viscosity of even the most fluid lavas is more than 50 times as great as that of water.† If one

* It is of course needless to call attention to the difference between fusibility and fluidity. A mass may be easily fusible but very viscous when fused, or it may fuse with great difficulty and when fused be very fluid. That a lava is very fluid does not indicate that it is considerably superheated. Water at 0° C. is sensibly as mobile as at 100°, though refined experiments reveal a difference.

† The viscosity of lavas is evinced by the slowness with which lava streams advance. Thus in the Kilauea eruption of 1840 the lava flowed eleven miles down a declivity of 1244 feet in two days, yet according to Wilkes and Dana (Characteristics of Volcanoes, 1890, p. 63) in this case the stream was fed from several fissures along its whole course instead of being an overflow from a single opening. The heat of the stream must have been pretty well maintained by such accessions. The average rate of flow of this lava down a 2 per cent slope was about ¼ mile per hour or 22 feet per minute. Now water in a stream of such a cross section on such a grade would flow at about 6 miles per hour or about 24 times as fast. Since lava is about 2·5 times as dense as water, these data roughly indicate for the kinetic viscosity 2·5 × 24 or 60 times the viscosity of water.

In the case of gases Maxwell shows that the diffusivity of mass is 1·5435 the kinetic viscosity (Theory of Heat, chapter 22) and that the ratio of diffusivity to viscosity in the case of liquids is much smaller than in gases. Hence it seems safe to assume the diffusivity of lava as not more than $\frac{1}{50}$ of that of a solution like that of bluestone.

In the more recent literature I have not met with investigations which throw light on the relations between diffusivity and viscosity. The resistance which molecules, atoms or ions meet when undergoing diffusion Ostwald illustrates by the slow subsidence of pulverized solids in air (Lehrbuch der Allgem. Chemie. vol. i, 189:, p. 698). This slowness is due, at least in part, to the viscosity of the air, and Stokes in 1851 showed that the resistance of spherical particles is proportional to the radius. As has been mentioned, viscosity is a resistance due to the diffusion of momentum. That viscosity impedes diffusion of matter appears evident, for example, from the behavior of sealing wax, which is an ultra-viscous fluid. Sticks of wax of different colors which have become adherent during hot weather do not diffuse into one another sensibly even after months of contact. On the other hand diffusion of crystalloids takes place in quasi-solid gelatine jelly at the same rate as in a fluid (Graham). This, however, I take to be not comparable to the action of a viscous fluid, but to the behavior of a colloid septum such as bladder, but of great thickness. The jelly seems to me to have a structure similar to a sponge of very fine grain preventing convection but not the diffusion of crystalloids. Colloids do not diffuse in such a jelly.

In discussing lavas it should not be forgotten that high temperature accelerates diffusion, which adds to the difficulty of making any estimate of the diffusivity of rock magmas.

In choosing as an illustration of diffusion an hypothetical magma with $\frac{1}{50}$ of the diffusivity of bluestone, I have been guided in part by observation on lavas. Lavas with this diffusivity mingled in thin layers, like banded rhyolite, would diffuse into approximate uniformity in a few hours. No one can doubt that the rhyolitic bands have been in contact for at least a few hours in the fluid state and that they must, therefore, be less diffusible than my hypothetical lava. Similar banding is not infrequent in andesites though it is less common than in rhyolite.

supposes the diffusivity of such a lava to be $\frac{1}{50}$ that of sulphate of copper solution, then the time needful to give a certain saturation at a certain point will be 50 times as great. It would take 50 years instead of 1 to establish the conditions given in the second column of the table. A million years is $20{,}000\times 50$ or $141^2\times 50$ and consequently in this vast period sensible impregnation of the lava would have extended to only about 49^m from contact (i. e. 141×35^{cm}) and semi-saturation to some 12^m.

It may seem to some readers that I have exaggerated the viscosity of lava. Certainly literature contains some accounts of lavas said to "run like water," but I have been able to find no approximately precise data indicating such fluidity. That most lava streams, those of Vesuvius, for example, advance even on steep declivities at a small fraction of a mile an hour is certain. It will be seen, however, that the arguments of this paper would not be essentially changed if lava were supposed no more viscous than a bluestone solution. But it may also be asked why even greater fluidity may not be assumed in lavas prior to eruption, a fluidity sufficient to allow of segregation in a moderate time. There seem to me abundant grounds for refusing assent to such an assumption. Hypogeal magmas must be under great pressure and they must be close to their melting points; for if they were considerably superheated the surrounding rock masses would melt and the temperature would fall to the melting point. To bring about considerable superheating would be almost as difficult as to boil water in a vessel of ice. The less viscous the magma the more difficult would superheating be. Now liquids which, like lava, condense in solidifying are most viscous at the melting point, and pressure increases their viscosity. Hence hypogeal lavas must be more viscous than they are when they reach the surface. The relief of pressure is equivalent to superheating. It is, therefore, irrational to assume that lavas prior to eruption are at all more fluid than they are at eruption. All indications point to the opposite conclusion.

These illustrations show that diffusion of fluids, particularly viscous ones, is an excessively slow process. It is instructive to compare its rate with that of the diffusion of heat. According to Lord Kelvin, the time required for the diffusion of common salt in water to be represented by a given curve is more than 870 times as long as that needful to diffuse heat through underground strata in such a way as to be represented by the same curve.* Copper sulphate requires five times as much time

* The diffusivity of heat in underground strata has an average value of 0·01. In Lord Kelvin's article on heat, Enc. Brit, 9th ed., vol. XI, p. 582, Table B (autograph issue), the time required for the diffusion of heat in underground strata should be given as 3,170,000 years instead of as $\frac{1}{10}$ of this period.

as salt and the hypothetical lava 50 times as much as the sulphate. Diffusion of matter in the lava, therefore, takes over 200,000 times as long as the diffusion of heat in solid rock at ordinary temperatures. Even if melted lava conducts heat many thousand times worse than solid rock, so that the conductivity of the fluid might be neglected, the temperature in an unequally heated mass of melted lava would be sensibly equalized by the conduction of the solid walls of the reservoir before any tendency to molecular flow which difference of temperature might have induced would have had time to produce sensible effects.

Now in any case of the segregation of homogeneous, miscible, fluid magmas by molecular flow, the available osmotic force is only the difference between two osmotic forces, and the transfer of a given quantity of matter to a given distance will be much slower than in simple diffusion. Hence, so far as I can see, a mass of lava of volume, say 1 cubic kilometer, would not have had time to segregate into distinctly different rocks by molecular flow if it had been kept melted since the close of the Archæan, even if the temperature of the top could have been kept sensibly above the temperature of the bottom. But it is very difficult to imagine how a mass of lava could be more highly heated at the top than at the bottom, since in general temperature increases with depth. If the bottom were more highly heated than the top, of course convection currents would be set up and those would effectually prevent any segregation on Soret's method. I do not think this method should be invoked in explanation of rock differences unless it can be shown how heating from the top can occur.

No such difficulties present themselves in such cases as that of the growth of a crystal. A supersaturated solution of a given substance cannot exist in immediate contact with the solid form of the same substance, but a solution may be supersaturated at a very short distance from the solid mass. In cases of crystallization there is thus an osmotic pressure-difference directed toward the growing crystal, and molecular flow results. The molecular flow attending the formation of phenocrysts is usually confined to distances of a few millimeters, or at most a few centimeters, and is clearly a process involving no unreasonable amount of time. Similarly the formation of aureoles of diffusion around blebs to distances of a few centimeters is not a very lengthened process. Thus if such a bleb had the properties of the hypothetical lava discussed above, an aureole 5^{cm} in depth might form around it in about a year, and sensible diffusion would extend to a distance of 1^{mm} in the comparatively short period of $3\frac{1}{2}$ hours.

Convection unavoidable.—It has been shown above that

segregation of magmas by the method of Ludwig and Soret would occupy a stupendous time even if a mass of melted lava could be kept free from convection currents. This freedom, however, could only be secured by permanent, regular decrease of temperature from the upper surface of the magma downwards. In any fluid of only moderate viscosity even a very small rise of temperature at the bottom would cause convection currents which in a day would undo the segregation it had taken thousands of years to accomplish by Soret's method. Lavas of very great viscosity would also mingle by convection far more rapidly than the most diffusible solutions could segregate through differences of temperature. Mingling again might occur in the absence of bottom-heating by any mechanical disturbance of surrounding rock masses.

That in general the temperature of the globe increases with depth is perhaps the best established generalization of geology. Hence even if it be granted for the sake of argument that in some particular locality the temperature decreases with depth, it is clear that such a thermal distribution is a case of unstable equilibrium. It can, therefore, only be temporary and it would surely be a strange exception were such an abnormal distribution of temperature to last for 1000 years. Yet in that time no segregation worth mentioning as an origin of rock differences could occur. The normal condition of a hypogeal molten magma must be that in which temperature increases with depth and in which convection effectually precludes any process of segregation by molecular flow.

Immiscible fluids.—Another method of segregation, which is quite distinct from that discussed above, depends upon changes in the mutual solubility of fluids. Some fluids which at certain temperatures mingle in all proportions dissolve one another only in certain proportions at other temperatures. Thus benzol and acetic acid mix without limit at 15°, but below this temperature separate out into two layers, one of which contains nearly twice as much acetic acid as the other. So, too, phenol and water mingle freely above 69°, but not below this temperature; and there are many similar instances. The phenomena were studied by Mr. Alexejew, who concluded that in all cases where the solutions do not react chemically upon one another they become miscible above a certain temperature.*

Though Mr. Alexejew studied some of the physical relations of solutions of fluids in fluids, he did not determine whether the passage from complete to partial miscibility is accompanied by expansion or contraction. This step, however, has been taken by Mr. Herman Pfeiffer in Prof. Ostwald's laboratory. He finds that this change is accompanied by a sudden sharp

* Wied. Ann., vol. xxviii, 1886, p. 327.

contraction of volume.* It appears to follow of necessity that at the temperature of complete miscibility under a given pressure an increase of pressure would resolve the homogeneous fluid into immiscible portions.

In close relation to this separation of a homogeneous fluid into different layers is the precipitation of a solid from a fluid. The process of solution of a solid is one involving the absorption of heat, and in general the solubility of solids increases with the temperature. Anomalous cases appear to be referable to changes in molecular aggregation, the formation of hydrates and like causes. The influence of pressure on the solubility of solids was first carefully investigated by Dr. Sorby†, and Mr. F. Braun‡ has more recently made a very thorough study of the subject. Experiments have naturally dealt almost exclusively with aqueous solutions at ordinary temperatures, and it must be borne in mind that as water is a fluid of very exceptional properties the direct results of experiments on solutions in water are not immediately applicable to other fluids such as lavas. Most substances dissolve in water under contraction of volume and only about half a dozen compounds are known which undergo dilatation during solution. Now when contraction takes place increase of pressure will and does assist solution. If contraction were a universal concomitant of solution the interior of the earth would be fluid. But Mr. Braun gives apparently sound reasons for believing that even in aqueous solutions under high pressure and temperature, dilatation and not contraction would attend solution. The investigations of Prof. Carl Barus§ and others and some observations of mine on dikes‖ show that lavas contract in solidifying. The frequent corrosion of phenocrysts is seemingly due to increase of solubility attending relief of pressure. Thus for magmas it appears that increase of pressure promotes precipitation of solids as well as segregation into distinct fluids.

Segregation by immiscibility.—In fluids which, though originally homogeneous, tend to break up into two or more immiscible parts, two distinguishable modes of separation may be followed. As the temperature of separation is approached, the walls of the vessel being cooler than the fluid, any component about to separate out will separate to some extent on the containing walls much as frost or dew forms on good conductors. It does not appear that any large part of a large mass of even a moderately viscous fluid could be segregated in this way, for the process involves molecular flow from the interior of the fluid.

* Zeitschr. phys. Chemie, vol. ix, 1892, p. 469.
† Proc. R. S., vol. xii, 1863, p. 538.
‡ Wied. Ann., vol. xxx, 1887, p. 250.
§ This Journal, vol. xliii, 1892, p. 56; vol. xlv, 1893, p. 1.
‖ North Amer. Rev., April, 1893.

Thus in a spherical mass of 100^m radius, if half of a component were thus to be deposited on the walls, a portion of this deposit would have traversed a distance of nearly 21^m by molecular flow, which would take thousands of years even in the case of a solution of bluestone in water.

If the separating fluid does not condense on the sides of the enclosing cavity, it must condense somewhat like fog in the mass of the fluid. Now in a very fluid mass, like water, the larger drops of such a fluid will rise or sink more rapidly than the smaller ones, coalescence will occur and the lighter fluid may separate out in a layer. But even in the case of a foreign material suspended in air viscosity greatly delays such separation. The clouds are substantially aggregates of small water drops which, because of the viscosity of the air, fall so slowly that the slightest current sweeps them along. So, too, dust remains suspended in the atmosphere because air is viscous.* In fluids such as lava it scarcely seems credible that any extensive separation of a precipitated immiscible liquid should occur. It may be that spherulites and perhaps some phenocrysts are crystallized from drops of such liquids. However this may be, it is certain that many of the phenocrysts form before eruption and remain suspended in the magma in spite of densities differing considerably from that of the medium.† Thus even in the process of the separation of fluids into immiscible or partially miscible fractions I can see no adequate explanation of rock segregation. Furthermore, if, as seems to follow from the law of fusion, magmas are not heated much above the melting point, there is but a small range of temperature within which such separations could occur and they would be correspondingly rare.

Heterogeneity of the earth.—If the physical theory of solution fails to account for rock segregation, two alternatives are left. Either segregation takes place in accordance with some principle of physics as yet undiscovered (*ignotum per ignotius*), or the facts which have led to the hypothesis of segregation are capable of a different interpretation not at variance with the known properties of matter and compatible with reasonable limits to geological time.

So far as I know, all geologists and astronomers are in unison

* The viscosity of media is probably only one of the influences affecting the subsidence of disseminated fluid or solid particles

† It is well known that phenocrysts in fresh surface-flows are often bent and even broken. Sometimes black borders have formed about hornblendes thus fractured. Such fractures must have happened during eruption. The lithologist will not require to be reminded that phenocrysts of augite and of amphibole with a density of say 3·25 are often of about the same size as those of feldspar with a density of say 2·65, yet there is as a rule no tendency to the separation of the lighter and heavier phenocrysts into distinct layers.

in the belief that the earth has been fluid, not indeed at any one time from center to its present surface, but at least to a great depth from the temporary surface of the growing globe. Yet the earth is clearly not a homogeneous mass, nor is it a system of concentric shells, each homogeneous. The mere fact that one hemisphere is almost entirely covered by water shows that the globe is of greater density below this great ocean than beneath the opposite continental surface. Were the shells homogeneous no continents could protrude above the sea. Were the earth of uniform composition no mountain ranges could stand above the plains. Were the material below the plains uniformly distributed there could be no anomalies of gravity such as occur near Moscow, in Kansas, and elsewhere. The distribution of feldspars in the western part of this continent shows lack of homogeneity, for on the Pacific slope potash feldspars are marvelously rare. No trachyte and extremely little typical granite is known from the Wahsatch range to the Pacific ocean. The distribution of metallic ores shows heterogeneity. Much more than 90 per cent of the known tin ores of the world lie in a belt stretching from the straits of Malacca to Tasmania. There has been deposition of mercurial ores in this belt also; but their quantity is insignificant. A belt of quicksilver deposits extends from British Columbia to Chili. In this belt there is tinstone at many points, but the total product of tin on this belt is scarcely worth mentioning. I can only infer from these facts that quicksilver is an extremely subordinate component of the earth in the Australasian region and that the globe contains little tin along the Cordilleran belt. It is needless to observe that in almost any small area the rocks show marked variations or that two hand specimens from the same locality are rarely indistinguishable. Deserving of special mention, however, are the striped rhyolites, the banded gabbros studied by Sir Archibald Geikie and Mr. Teall, and the ribbon gneisses so abundant, for example, in the southern Appalachians. The rhyolite at least has been fluid, and most geologists consider gabbroitic and granitic magmas as fluids. The diffusion exhibited in these cases is slight and sometimes hardly perceptible to the naked eye, yet it is scarcely supposable that these bands were not in contact for days at least in their mobile state. Now my hypothetical lava would diffuse to the depth of a millimeter in three or four hours. Hence these sharply banded rocks must be much less diffusible than my assumed lava and the diffusivity of the granular rocks and their fluidity would scarcely exceed zero.* Thus from the surface of the globe to its minutest

* Banding such as is found in gneiss and rhyolite could not result directly from segregation on Soret's methods or by difference of pressure, for these processes

portions there are clear indications of heterogeneity, notwithstanding that similar rocks and similar series of rocks occur in widely dispersed localities.

Is there any valid indication that uniformity ever reigned? It used to be thought that the Archæan rocks were uniform, but it is well known now that they are not so. The early eruptions and intrusions seem quite as diverse as the modern ones, excepting so far as original differences are masked by metamorphism. The theory of the permanence of continental areas has many very strong supporters, and that land areas have existed since the Cambrian seems certain. The mountain system of the world in its larger features appears to have been outlined during the Archæan, and there are observations indicating a highly accentuated topography even in those days. Were the indications of heterogeneous composition confined to the immediate neighborhood of the earth's surface, it might be maintained that these inequalities had been brought about since consolidation, but everything tends to show that only the shell of the earth next to the surface and a few miles in depth partake sensibly in orogenic movements, while several of the evidences of heterogeneity point to inequalities at great depth.

Uniformity unattainable.—If the earth condensed from a nebulous ring, it is fairly inconceivable that the successive shells of the growing mass should each have been uniform in composition; and if the origin of the earth is a ring thrown off from the sun, the coalescence of this ring to a globe cannot have resulted immediately in uniform distribution of matter. The sun spots show that the sun is not even yet an aggregate of shells each uniform in composition. The exterior layer of the globe must have retained such fluidity as it possessed for a very long time, and must have passed by insensible gradations through every temperature between the initial one and that of consolidation. Had the various component portions of this layer been of large size, of low viscosity, and not miscible with one another, they would have arranged themselves in the order of density quite irrespective of chemical composition. If the masses were viscous, however, nothing like a perfect separation according to density could occur in

can lead only to very gradual transitions. Banding might conceivably result from such a segregation followed by active stirring, but only on condition that stirring was immediately followed by solidification, for otherwise diffusion would restore homogeneity. Separation of a magma into immiscible portions followed by active stirring might also produce banding, but again only on condition of immediate consolidation, since otherwise separation into two layers would again take place and much more rapidly than at first.

Miscible substances in contact which do not diffuse at a finite rate can have no sensible vapor tension and must be solids or ultra viscous fluids. Immiscible fluids must have a perfectly sharp contact like that between a lead button in an assayer's crucible and the enveloping slag.

this way and only a rude approximation to regularity would be attained.

If the melted masses were partially or wholly miscible, much the same arrangement would take place at first because diffusion on any large scale is at best a relatively slow process. Then diffusion and convection would come in play, tending to equalize the composition.

On the other hand, unless the originally heterogeneous masses had very different properties from those of remelted rocks, whether of Algonkian or modern time, they cannot have diffused on any large scale, and uniformity along equipotential surfaces cannot have been attained even if fifty million years were allowed for the process, unless the convection currents were so powerful and universal as to break up the original masses into streaks of a few meters in width. I see no cause for convection so active as this. In the nebulous state the material of the earth must have assumed some approach to convective equilibrium of temperature, and though here and there the solidifying globe may have been affected by disturbances of frightful intensity, analogous to sun spots, a general diversity of temperature sufficient to stir the whole or most of the melted layer into uniformity seems utterly improbable.

What is known of the properties of matter seems to me to point to the hypothesis that the material of the earth is rudely arranged by density irrespective of chemical composition, the different masses mingling for a few meters or scores of meters along their common boundaries, this structure being due to original heterogeneity. If segregation took place at all, prior to the consolidation of such a globe, this process would be limited to particular masses and would tend to still greater heterogeneity.

Hypogeal refusion.—Consider now the effect of the refusion of any portion of the earth's mass. Unless the temperature of the magma were raised essentially above the initial temperature of the molten globe, or unless it were melted at a very different pressure, the magma would simply be restored to the condition in which it existed before the primal consolidation. There is no indication that lavas prior to eruption are really raised to temperatures greatly above that of fusion, for almost all of them bring solid phenocrysts to the surface, nor is it easy to see how they could be heated much above the melting point, for so long as there was unfused material of a similar character in the neighborhood of the subterranean mass undergoing fusion, any heat increment would of course melt more rock instead of raising the temperature of that already fused. Thus it is substantially certain that in the molten globe

a given magma passed very gradually through the temperature at which it has more recently been remelted. As for the pressure, it seems possible that under continental areas a given fusing subterranean mass may exist under a somewhat smaller load than that to which it was subjected at primal consolidation, for the general tendency of continents is to upheaval and degradation by erosion. If this change of pressure is of any consequence at all, it will tend to make the refusing mass more fusible and more miscible.

If now the mass were both homogeneous and in molecular equilibrium before the primal consolidation, it may be in equilibrium after refusion. If the pressure is smaller than the original one, this difference would have no tendency to promote segregation. If by some almost inconceivable coincidence, the upper portion of the refused mass were heated to a higher temperature than the lower part, this temperature would be equalized by conduction through the walls, if not through the liquid, before any sensible segregation could occur.

If the mass were heterogeneous in consequence of primal segregation, fusion would again tend to restore molecular equilibrium and the only chance of a new segregation would lie in the possible difference between primitive and ultimate pressure, which, if positive, would tend to mixture rather than to separation.

If the mass were heterogeneous because the primal fusion had not continued long enough to bring about homogeneity, refusion would be accompanied by a tendency to continue the process of molecular flow and to decrease the heterogeneity of the mass; but even if the refused mass were kept molten for a million years, this tendency would probably have only insignificant results.

Mixture by eruption.—Little or nothing is known of the process of refusion of subterranean masses to eruptive magmas. Supposing a mass which is fused and near its melting point to remain in its subterranean reservoir, it must in general receive or lose heat. In the latter case it will reconsolidate, in the former the mass of melted material will increase. In the case of rocks, fusion is accompanied by expansion and the magma must have more space than it occupied in a solid condition. Any elastic strains in surrounding masses will also tend to expel it and it would seem to me most probable that magmas are expelled as soon as the mass of melted material had increased to a certain limit dependent upon local conditions. If so, there must be little time for the fulfillment on a large scale of a process so slow as molecular flow. Doubtless fusion may be confined to a nearly homogeneous portion of the earth's lithoid shell. If the hypothesis explained above of

primitive, unmingled, unsegregated masses is correct, a good many of these must have the composition of augite-andesite; for this as well as several other simple rock types has issued at most distant points with almost constant characteristics. Fusion may, however, also affect two or more diverse masses and then eruption tends to mingle them. Ejection through pipes or fissures must indeed be a most efficient stirring process, and since relief of pressure is accompanied by depression of the melting point, different magmas thus ejected are superheated and may mingle to an observable extent by diffusion before they finally consolidate. In such cases one would probably find two (or more) rock types accompanied by mixtures of variable composition. Again, a fissure through which different types were extruded successively or in mixture might at the close of the eruption be filled with a single type or with a mixture. If such a mixture were at all intimate, diffusion would mask the original differences and the case would be one of apparent transition.*

Possibly some of the observed occurrences which have led to the hypothesis of differentiation are really of this character, for I think it has been shown in the foregoing pages both that transitions can be explained on the hypothesis of primitive heterogeneity and that the explanation of differentiation itself presents formidable difficulties. I do not see why it should be necessary or desirable to assume that in the early history of the globe the vast shell from which eruptions issue was reduced to substantial uniformity. Experience affords no analogy in support of such an assumption nor has any theory been propounded which will account for it.

If primitive heterogeneity is still an important feature in the earth's structure, and if unmingled magmas represent primitive differences, the labors of lithologists would naturally be directed to detecting these original types. These would probably be recognizable by their wide distribution and constant character. Then areas of rapid variation would be regarded as representing mere mixtures and it might be possible to reduce instead of increasing the number of rock species.

Abstract.—All known processes by which the segregation or differentiation of a fluid magma could take place involve

* The order of mixture and extrusion would seem to depend on many circumstances, among others on the shape of the subterranean reservoirs. If this were a cone with its vertex nearest the surface, the disposition of the ejecta would be very different from that which would be observed if the reservoir were a flattened lens with its edge horizontal and a vent on one surface. If each eruption represents a separate melting, still other dispositions will result. It appears to me anything but remarkable that different observers find eruptions in different areas taking different orders. Gradual solidification from fissure walls of dike magmas circulating by convection may lead to preponderance of less fusible ingredients near the edges of a solid dike.

molecular flow. This is demonstrably an excessively slow process excepting for distances not exceeding a few centimeters. Soret's method of segregation, even if it were not too slow, seems inapplicable because it involves a temperature unaccountably decreasing with depth. The normal variation of temperature, an increase with distance from the surface, would be fatal to such segregation. The least objectionable method of segregation would be the separation of a magma into immiscible fractions; but this seems to involve a superheated, very fluid magma, while the law of fusion and the distribution of phenocrysts in rocks indicate that magmas prior to eruption are not superheated to any considerable extent and are very viscous.

The homogeneity of vast subterranean masses called for by the hypothesis of differentiation is unproved and improbable. The differences between well-defined rock types are more probably due to original and persistent heterogeneity in the composition of the globe. Hypogeal fusion and eruption tend rather to mingling than to segregation, and transitional rock varieties are not improbably mere fortuitous mixtures of the diverse primitive, relatively small masses of which the lithoid shell of the earth was built up.*

Washington, D. C., October, 1896.

*I owe thanks to Dr. Arthur A. Noyes of the Mass. Institute of Technology for kindly examining the manuscript of this paper. Dr. Noyes's reputation as an investigator in osmotic questions gives his approval of my argument great value.

Art. IV.—*On Igneous Rocks from Smyrna and Pergamon;* by Henry S. Washington.

Of the specimens described in the following brief notes those from Mt. Pagos near Smyrna and from Pergamon were collected by the writer in the spring of 1892. Those from the other Smyrna localities were collected by Mr. J. S. Diller in the summers of 1881 and 1882, who most kindly presented them and his notes for use in the preparation of this paper. It may be mentioned, in justice to him, that these form but a small part of those he collected, the rest not being available in time for publication. The writer gladly avails himself of this opportunity of expressing to Mr. Diller his heartiest thanks for his kindness and generosity. It must be premised that these notes are but fragmentary and that their publication seems only justified by the scantiness of our knowledge of the rocks of Asia Minor.

Augite-andesite, Smyrna.—The city of Smyrna lies at the head of a deep gulf in the west coast of Asia Minor and is surrounded on three sides by igneous rocks. To the northwest are the hills of Phocæa, probably of andesites and their tuffs; to the north and northeast the andesitic masses of Yamanlar Dagh and Mt. Sipylos; and immediately to the south and southwest a ridge of igneous rock formed of the hills of Mt. Pagos, Kara Tash and Giöz Tepé. Since the early descriptions of Hamilton* and Tchihatcheff,† little or nothing has been written on the geology of this region, with the exception of a short paper by vom Rath.‡ Of the rocks of Phocæa and the Sipylos ridge I have no specimens, so that we must confine ourselves to those from the immediate vicinity of Smyrna. From the brief descriptions of vom Rath§ and the notes of Mr. Diller, it seems that the Sipylos rocks are closely similar to those of Mt. Pagos, and Mr. Diller also compares them in places with the "hypersthene-bearing andesite by Assos."

Mt. Pagos, 185^{m} high, is the eastern end of a ridge, up the northern and eastern flanks of which the modern city of Smyrna extends, and which formed in antiquity the ancient acropolis or citadel, the summit being still crowned with ruined walls. It is composed of a mass of andesite which, according to Hamilton and Tchihatcheff, has been forced up through underlying beds of Cretaceous (?) limestone. In many places

* W. J. Hamilton: Researches in Asia Minor, London, 1842, i, 54; also Hamilton and Strickland, Trans. Geol. Soc., London, ii, 293.

† P. de Tchihatcheff: Asie Mineure, Géologie, i, Paris, 1867, pp. 69–73.

‡ Vom Rath: Sitzber. Niederrh. Ges zu Bonn, 1882, pp. 16–26.

§ Quoted in Roth, Geologie, ii, 326, 1883.

the andesite is overlaid by masses of detritus containing numerous shells, and here and there accumulations of shells are found, principally of oysters and scallops (murex); snail shells also abound, which closely resemble the numerous land snails of Greece, so far as I was able to judge. Fragments of pottery, mortar and charcoal are also found in the detritus, and these deposits seemed both to Mr. Diller and myself to be in reality "kitchen-middens" rather than deposits from water or old beaches. Mr. Diller's notes, however, show that along the Meles River the andesite is overlaid by soft travertine-like limestone, apparently a lacustrine deposit. In places also andesitic conglomerates were observed.

The general mass, however, is very compact and shows, especially toward the west, a beautifully banded structure, the bands being red and black. The greater part of the mass visible is reddish, the color being due, as we shall see, to decomposition. The freshest rock has a dark gray groundmass, carrying numerous phenocrysts of feldspar and augite and fewer of biotite. Its texture is harsh and in cavities are found small crystals of biotite and acicular hornblende, with globular masses of a zeolite which vom Rath regards as a natrolite. Fine mammillary hyalite is also abundant. The specific gravity of a fresh gray piece was found to be 2·640 at 17° C.

Under the microscope the rock is seen to be composed of plagioclase, diopside and biotite, with accessory magnetite, apatite and zircon, lying in a glass base. Neither hypersthene, hornblende, olivine nor quartz was seen in any of the specimens. The structure is eminently the vitrophyric of Rosenbusch and is well shown in fig. 4 of Tafel v of his Mikroscopische Physiographie, vol. ii.

The plagioclase phenocrysts are often well shaped, but in many cases fragmentary. They are clear and carry only few inclusions of glass, apatite and zircon. Zonal structure is common, the interior being, as usual, the more basic. Nearly all show well-developed twinning lamellæ according to the albite law, and here and there pericline twinning is seen. Examination of sections on $b(010)$ by Michel Lévy's method* showed extinction angles of 20° and 25° on each side of the twinning plane, indicating a labradorite of the composition Ab_1An_1, or somewhat more basic. The few feldspar phenocrysts that showed no lamellæ could not be identified with certainty as orthoclase. The diopside phenocrysts are often well-shaped, though fragments occur. They are almost colorless and clear, and carry only few inclusions of brown glass and magnetite. Some twinning parallel to $a(100)$ is seen, but zonal structure is uncommon. Biotite phenocrysts, in stout hexagonal prisms,

* Michel Lévy: Détermination des Feldspaths, Paris, 1894.

are not as common as diopside. They are deep brown, strongly pleochroic, and basal sections show a slight dispersion of the axes parallel to $b(010)$. They are quite fresh and only slightly altered on the edges to a narrow opacitic border, with rounded angles.

The groundmass in general is typically hyalopilitic, the microlites being mostly of labradorite, with fewer of what seems to be orthoclase, some small colorless diopside prisms, many magnetite grains, and a few small crystals of apatite and zircon. These generally show flow-structure. The glass base is usually colorless, though sometimes light brown.

The preceding description applies especially to the fresh gray specimens. The red ones show much the same features, the differences being due to decomposition. Thus in these the augites are colored red or black on the edges, the biotites are a dark red brown, and the groundmass is much decomposed with limonitic products very abundant.

An analysis by the writer of a typical, fresh, dark gray specimen from near the top of Mt. Pagos is inserted here. Its sp. gr. is 2·640 at 17° C.

SiO_2	60·68
Al_2O_3	16·19
Fe_2O_3	5·37
FeO	1·58
MgO	2·96
CaO	5·88
Na_2O	3·11
K_2O	3·95
H_2O	0·98
	100·70

It it high in silica and alkalies for an andesite and with rather low alumina. The potash is considerably higher than soda, which would account for the presence of some orthoclase in the groundmass, since biotite is not very abundant, though part of it may belong to the glass base. On account of the vitreous character of the rock it is scarcely practicable to calculate from the analysis a possible mineralogical composition. There is, however, more SiO_2 than enough to satisfy all the other constituents, even assuming that all the K_2O is in orthoclase, which, of course, is not the case; so that quartz would have separated out if the rock had been formed under conditions allowing of a holocrystalline development. On this account the rock might be properly called a dacite.

The rocks of Kara Tash (Black Rock) 2^{km} west of Smyrna, three specimens of which were sent me by Mr. Diller, differ

considerably from those just described. Rosenbusch* describes rocks from this locality as biotite-hypersthene-andesite. I was unable to find any hypersthene in the specimens examined, and the microphotograph he gives resembles very much my sections of the Pagos rocks, and is of a totally different character from all of those of the Kara Tash rocks sent by Mr. Diller, so that it seems probable that the locality of his specimen is incorrectly given.

The Kara Tash rocks are all very dark and compact, showing numerous small glassy feldspars, and a few augite and biotite phenocrysts in a very dark brown or black, highly vitreous groundmass. Some evidences of flow-structure are seen in the hand specimen and are even more marked in the mass, judging from Mr. Diller's notes.

Under the microscope the very well-shaped feldspar phenocrysts are seen to be of labradorite a trifle more basic than Ab_1An_1. They are clear and fresh and show, almost without exception, twinning lamellæ, while zonal structure is frequent. Inclusions are not very abundant, and consist mostly of small spots of dusty brownish glass, with a few apatites. The very pale green diopsides are highly automorphic, perfectly fresh and contain few inclusions. The not very numerous biotites are greenish brown and perfectly fresh, even incipient alteration not being seen. Some large, well-shaped magnetite grains may also be classed among the phenocrysts. The very abundant groundmass is highly vitreous, the glass being quite colorless, and only rare small crystals of augite, feldspar, magnetite and apatite being present. It is chiefly remarkable for the very great abundance of trichites, with which it is thickly crowded. By far the greater part of these are curved, sometimes to a high degree, but some straight ones are seen. Though under low powers they seem opaque, yet high powers show the majority of them to be clear and colorless. Those which seem black and opaque under these conditions probably owe their appearance to their excessive tenuity. What the nature of these minute bodies may be it is impossible to say, since they exert no action on polarized light. The most natural supposition is that they are either diopside or feldspar, and I am inclined to consider them the latter,—probably orthoclase,—basing my opinion on the results of analysis and their rather remote analogies with forms seen elsewhere. Quite well developed flow-structure is observed, which is brought out more prominently by the presence of some narrow dusty gray streaks. The specific gravity was found to be 2·601 at 18° C., the lower figure as compared with that of the Mt. Pagos specimen being chiefly due to the more highly vitreous character.

* Rosenbusch: Mikr. Phys., ii, 890, 1896, also Taf. v, fig. 4.

An analysis of the rock of Kara Tash by the writer is given. As will be seen, it resembles in general that of the Mt. Pagos

SiO_2	61·93
Al_2O_3	18·47
Fe_2O_3	1·93
FeO	2·23
MgO	2·66
CaO	4·31
Na_2O	2·92
K_2O	3·92
H_2O	2·28
	100·65

rock, though silica is somewhat higher and lime a little lower, while alkalies, ferrous oxide and magnesia remain almost exactly the same. Alumina is, however, much higher and ferric oxide lower. Water also is much higher, which may be attributed to the abundant glass.

One of Mr. Diller's specimens from the coast 4^{km} west of Smyrna, between Kara Tash and Giöz Tepé, shows very clearly the red and black banding already mentioned. The black bands resemble the rock just described, while the red look more like the Pagos specimens.

Under the microscope both bands resemble somewhat more the Pagos rock than that of Kara Tash proper, though they differ from either. The phenocrysts, which are of labradorite, diopside and some biotite, are often fragmentary and the finely automorphic crystal boundaries of the Kara Tash phenocrysts are lacking. The red bands show a slight brown coloration of the diopsides and biotites, with limonitic spots here and there. The base is a clear colorless glass, and is quite hyalopilitic through the presence of numerous minute, *straight*, transparent, colorless trichites, with some larger feldspar laths. The groundmass of the black streaks shows in addition large amounts of fine "dust," which gives it a dirty appearance and greatly interferes with its transparency. In this it resembles the dusty streaks of the Kara Tash specimens.

Another specimen from the coast 3^{km} west of Smyrna shows a fine-grained reddish groundmass containing very many glassy feldspars and some small brown spots representing original augite and biotite crystals. In thin section it greatly resembles the red Pagos rocks, and all except the feldspar is much decomposed. The diopsides are all deeply bordered with brown, the biotites are all entirely reduced to brown rusty masses, and the groundmass is much decomposed and dirty.

Another specimen from near the same place shows a dark,

slightly greenish gray, waxy groundmass, with the usual phenocrysts. It contains also an angular enclosure of a fine-grained reddish rock, showing only few phenocrysts of feldspar. This is separated in part from the enclosing rock by a crevice, the walls of which are lined with crystals of prehnite. Seen in thin section, the main rock is seen to be much decomposed, but resembled originally the red bands just described. The labradorite phenocrysts are fresh, but the diopsides and biotites are decomposed as before, though the product is rather darker. The abundant vitreous groundmass is of a brown glass, rather dusty, and the numerous straight trichites are black through decomposition.

The reddish enclosure is so thoroughly decomposed as to render examination very unsatisfactory. It is evidently a volcanic rock, probably more basic than the andesites previously described, and allied to the olivine-free basalts. The only phenocrysts visible in thin section are of colorless diopside, in stout prisms often with pyramidal terminations. These show the usual brown decomposition border. The groundmass is much decomposed in general to an indeterminate dirty mass, with spots of calcite here and there. In parts of the slide, however, it preserves fairly well its original structure—being composed of long slender prisms, or perhaps sections of plates, of feldspar, with interstitial brown glass base. These feldspars show no twinning, and in many cases extinguish parallel to their length, or nearly so, while in others the extinction is oblique at angles up to 26°. We may then suppose them to be of orthoclase or oligoclase, and labradorite. In general they form groups of needles parallel to each other, but in a few cases compose sheaf-like, diverging forms. No evidence of the former presence of olivine or biotite could be made out.

The only specimen of the rock of Giöz Tepé* (Eye Hill) shows a compact, greenish gray groundmass, with brownish feldspars and a few small augites and biotites.

Under the microscope this also is seen to be somewhat decomposed, though in a different manner from the preceding. While the substance of the feldspar phenocrysts is fresh, yet they are traversed by numerous brown dusty cracks, and their glass inclusions are all similarly altered. The few augite phenocrysts present are pale green and quite fresh, without the usual dark borders. The dark green biotités are profoundly decomposed, though there is usually a core of unaltered substance. There are also present many rather long stout prisms of a dull, opaque, brownish, granular decomposition product,

* This is the name as given on Kiepert's Map of Western Asia Minor (Berlin, 1892), and is not an uncommon one in the country. Rosenbusch renders it Yous Tepé.

the original mineral being entirely gone. It may have been augite, or perhaps more probably hypersthene. A few larger patches are reminiscent of magmatically altered hornblende. The groundmass is much decomposed, but not sufficiently so to hide the fact that it is holocrystalline and largely of feldspar, with numerous now rusty remains of long ferromagnesian microlites and laths. Serpentinous patches are also present. It must be noted that the rocks of Giöz (Yous) Tepé are referred by Rosenbusch to biotite-augite-andesites.*

Finally, a specimen from a locality "3^{km} south of Smyrna in the railroad cut where the aqueduct crosses the Meles River," may be briefly mentioned. This resembles the gray rocks of Mt. Pagos, but is rather decomposed. Under the microscope the phenocrysts of plagioclase and augite are rather less abundant, and only few of biotite are to be seen. The groundmass is also gray and thickly sprinkled with dusty grains and microlites, and there is little or no evidence of flow. Greenish andesites are also reported by Diller from this neighborhood, whose color is apparently due to decomposition.

Biotite-dacite, Pergamon.—The hill which formed the acropolis of the ancient Greek city of Pergamon lies 25^{km} east of the coast and some 60 north of Smyrna. It stands at the junction of two small streams which unite here to form the ancient Kaïkos. It is 310^{m} high—the southern end of a long ridge which rises steeply from the surrounding alluvial plain. In structure the hill apparently much resembles Mt. Pagos, but I do not feel competent to discuss this point, as my examination was too cursory.

The rock of which it is composed varies rather more than at Mt. Pagos, being generally a hornblende-free, but sometimes a hornblende-bearing, biotite-dacite, which also carries orthoclase in considerable amount. As the presence of hornblende does not affect the other characters, the varieties may be described together. A few tuff-like masses were also seen.

The rocks of Pergamon have been described by J. Roth† and Lepsius.‡ The former briefly notes that sanidine, abundant plagioclase and biotite, and rare green augite, occur in a compact gray groundmass. No augite was seen by either Lepsius or myself and was probably hornblende in reality. The description of Lepsius closely agrees with mine, though he notes no spherulites and speaks of the hornblende and biotite as brown.

Over the greater part of the hill the rock is gray, but in places, as in some of the long slopes and near the Temple of

* Rosenbusch. Mikr. Phys., ii, 889, 1896.
† Roth: Geologie, ii, 248.
‡ Lepsius: Geologie von Attika, Berlin, 1893, 168.

Julia at the north end, it is reddish. It is highly porphyritic, resembling the Pagos rock, the dacites and andesites of Aegina and Methana, and some of our western porphyries. Phenocrysts of feldspar, dark biotite, and fewer of hornblende (when present) are thickly scattered through the fine-grained groundmass, without any evidence of flow structure. The specific gravity of the freshest specimen, which was also that chosen for analysis, was found to be 2·525 at 17° C. It is thus notably lighter than the Smyrna rocks, which is probably to be connected with its higher silica content and more vitreous structure.

When examined in thin section the feldspar phenocrysts are found to be chiefly of plagioclase, with a smaller number of orthoclase. In the former the extinction angles of the twinning lamellæ indicate a labradorite of the composition Ab_1An_1. The sanidines are distinguished by their lack of multiple twinning (even Carlsbad twins being rare), their lower refractive index and their parallel or nearly parallel extinctions. The feldspars are very clear and glassy, and contain only a few inclusions of glass and apatite, with very rarely a crystal of biotite. The biotites are, when fresh, of a slightly brownish olive-green, and show no signs of magmatic alteration. In the reddish specimens they are browner in tone and are somewhat decomposed. The hornblende phenocrysts are well-formed, stout prisms of a dark, olive-green color, pleochroic, and perfectly fresh and unaltered. Augite phenocrysts are wanting entirely.

The groundmass varies considerably in structure. In most specimens it is very abundant and highly vitreous. It is more or less hyalopilitic, but not very thickly so, through the presence of feldspar laths, which are mostly plagioclase, with fewer of orthoclase. In one or two slides small square sections of orthoclase are abundant. Along with the feldspar laths are shreds of biotite and some magnetite grains and apatite needles, but no augite microlites. The glass base is colorless or slightly brown, and darker brown spherulites are often present. These are usually irregular in outline and possess a radiate structure, showing between crossed nicols an ill-defined cross. These spherulites are especially abundant in a specimen from near the great Zeus Altar. Perlitic cracking is also observable in many slides. In a few cases, as near the Temple of Julia and south of the Theatre, the base is microfelsitic and brownish in color, probably due to devitrification through decomposition.

For the accompanying analysis (No. 1) by the writer, the freshest specimen was selected from about halfway up the southeast slope. It is gray and contains considerable hornblende. Lepsius's analysis is added for comparison (No. 2).

	1	2
SiO_2	63·17	61·93
Al_2O_3	17·15	16·45
Fe_2O_3	2·84	4·66
FeO	1·31	0·40
MgO	2·17	2·94
CaO	4·17	4·40
Na_2O	3·08	4·03
K_2O	4·19	2·20
H_2O	2·51	2·50
	100·59	99·51
Sp. gr.	2·525	2·539
	17° C.	15° C.

The analyses resemble in general those of the Smyrna rocks, especially that of the Kara Tash specimens. Silica is, however, considerably higher—so high, indeed, that the name dacite is justified, though no quartz has crystallized out.* Iron oxides, magnesia and lime are all lower than at Smyrna. There is a discrepancy in the quantities of the two oxides of iron in the two analyses, but their total amount is about the same. There is also a discrepancy in the alkali determinations, though here again their total amount is about the same. Lepsius' differ from the others in showing higher soda than potash, which is rather surprising when the abundance of biotite and the presence of orthoclase are considered. The high H_2O is largely to be referred to the abundant glass base, though some of it belongs to the biotite molecule.

General remarks.—It would be of much interest to compare the rocks just described with the other volcanic rocks of western Asia Minor. At the present time, however, we are confronted at the outset of any such inquiry by the insurmountable obstacle of almost total lack of data, i. e. of modern petrographical and chemical descriptions. An examination of the geological map of Tchihatcheff shows that a line of volcanic centers extends along the west coast from Smyrna northward, including the areas of Smyrna, Sipylos, Phocæa, Yund Dagh, Pergamon, Dalanlar (Kiepert, Doghanlar), the extensive district of the Troad, and Kapoudagh on the Sea of Marmora. As we have already seen in the case of the Assos rocks (page 41), and as may be inferred from the brief descriptions of Tchihatcheff and Diller† the andesitic rocks of these centers much resemble each other. According to Diller, in the Troad some of them carry hypersthene, and they are associated with

* Cf. Küch: Vulk. Gest. Republ. Colombia, Berlin, 1892, 19; also H. S. Washington: Jour. of Geology, iii, 21, 1895.

† Diller: Quart. Jour Geol. Soc., xxxix, 632, 1883.

basalts, nepheline-basalts and rhyolites. There is some evidence of the Troad rocks being on a line extending westward through Mytilene and Samothrace,* where quartz-trachytes, trachytes and basalts occur, to Thessaly, where basalt is found at Persufli.† Since the analyses of the andesitic "basalts" of Mytilene and Persufli offer certain analogies with the rocks of Smyrna and Pergamon, they may be here inserted.

	1	2
SiO_2	56·58	53·61
TiO_2	0·77	0·34
Al_2O_3	14·88	16·11
Fe_2O_3	2·31	3·05
FeO	3·04	4·45
MnO	0·16	0·14
MgO	3·76	6·80
CaO	8·69	7·00
BaO	0·07	---
Na_2O	3·36	3·95
K_2O	2·18	3·08
P_2O_5	0·15	---
H_2O	2·12	1·65
CO_2	2·32	---
	100·39	100·18

No. 1‡ is of the Mytilene rock, but I can find no description of it. Lepsius describes the Persufli rock (No. 2) as a quite typical olivine basalt, amygdaloidal, and somewhat decomposed. The interest in these at present chiefly centers in the high alkalies, in which they resemble the rocks above, though soda is slightly higher than potash. The two resemble each other quite closely and the potash is high enough to lead one to infer the presence of orthoclase.

It is of interest also to note that an augite-hornblende-andesite is described by Becke§ from the Island of Chios, which lies west of Smyrna. This is propylitic in habit and is compared by him with the andesites of the Bosphorus.

South of Smyrna no igneous rocks are noted on Tchihatcheff's map till the promontory of Budrum (Halicarnassos) is reached. These, however, as well as the rocks of Kos and Nisyros near by, are, as I have pointed out elsewhere,‖ probably connected with the Aegina-Santorini line, the rocks of which show lower alkalies, with soda higher than potash.

* Niedzwiedzki: Tsch. Min. Mitth., 1875, 89. † Lepsius, op. cit., 169.
‡ Chatard anal., Bull. U. S. G. S., No. 60, 1890, 158.
§ In Teller: Geol. Beob. Insel Chios. Denksschr. Akad. Wiss. Wien, xl, 347, 1880.
‖ H. S. Washington: Jour. of Geology, iii, 158, 1895.

ART. V.—*Revision of the Genera of Ledidæ and Nuculidæ of the Atlantic Coast of the United States;* by A. E. VERRILL and KATHARINE J. BUSH.

(Brief Contributions to Zoölogy from the Museum of Yale University, No. L.)

A SOMEWHAT extended study of the series of deep-sea bivalves belonging to these families, dredged off our coast by the U. S. Fish Commission, from 1872 to 1887, has compelled us to revise the known genera and subgenera and to propose several new groups. In view of an unexpected delay in the publication of the report upon these families, which had been completed and fully illustrated, it seemed desirable to publish a brief preliminary account of the classification adopted.

These families are often united by modern malacologists under a single family (Nuculidæ), while others regard them as distinct. They are certainly closely related anatomically, as well as by the structure of the shell. Thus all the members of both families have a single pair of simple "foliobranchiate" (or protobranchiate) gills; two pairs of large labial palpi, the outer ones furnished with long extensile labial tentacles; a large muscular foot with an expanded, concave, terminal disk, adapted for rapid motions in jumping and swimming, as well as for creeping; and all have two series of transverse teeth on the hinge-margin. The peculiar structures of foot and gills appear together elsewhere only in the family Solemyidæ, which is evidently a related group, though it lacks hinge teeth. As these three families have gills of a peculiar and simple structure, each one consisting of two rows of flat lamellæ, attached to a single stem, they have recently been regarded as forming a special order (Protobranchiata).

This group is of special interest because of its great antiquity. Large numbers of fossil forms, very closely allied to existing genera and species, occur even in Silurian and Devonian formations.

Thus the common living genera *Nucula* and *Leda* are represented by numerous Devonian species, many of which cannot be separated from the recent forms, even as subgenera, by any tangible characters. Other species of the same age, referred to *Palæoneilo*, agree in nearly all essential characters with the living genus *Tindaria*. These fossil shells are generally larger and stronger than the corresponding living species. Many palæozoic genera which are now extinct were as highly organized and as much specialized as their living allies.

The thin-shelled, strongly siphonate genera, such as *Yoldia*, *Yoldiella*, etc., do not appear so early in geological time and

may be regarded as more modern specializations of the Leda-like forms. They are also the forms that swim and jump with the greatest activity. Therefore the thin and light character of their shells may be regarded as having been secondarily acquired, partly in consequence of their active movements, in which a heavy shell would be disadvantageous, and partly because the development of long siphons enables them to live concealed, much of the time, beneath the surface of the soft mud in which they generally live. In *Solemya* the shell is still lighter and thinner, in accordance with more developed swimming habits, combined with burrowing when at rest. Such forms as *Nucula* and *Tindaria*, which have no siphon tubes, must live at or near the surface of the mud over which they creep with their large expanded pedal disk. (Fig. 15.) These have for their protection comparatively solid shells, similar to those of palæozoic species, in form, texture, and sculpture.

The family Nuculidæ differs from Ledidæ mainly in having no siphon tubes, the mantle edges being completely disunited. The Ledidæ are remarkable for the great variations in the structure of the hinge-teeth, ligament, cartilage, and mantle, as well as in the form of the shell. The pallial sinus may be wanting or well-developed. Some genera have long united siphons (*Yoldia*); some have shorter ones, more or less separated (*Leda*); while in *Tindaria* there is no true siphon, but only an efferent orifice differentiated. The ligament may be wholly external, as in *Malletia*, *Tindaria*, etc., or it may be rudimentary and replaced by an internal cartilage or "resilium"; or both may coexist in varying degrees of development and degeneration. The hinge-teeth may be very numerous and regularly V-shaped, in each series, or they may be comparatively few and irregular, sometimes becoming oblique and lamelliform (*Silicula*). The beaks generally turn backward (*Yoldia*, *Leda*, *Nucula*), but in *Malletia*, *Tindaria*, and some other genera, they turn forward. On this account, when there is neither pallial sinus nor external ligament, it is often difficult, if not impossible, to tell which is the anterior end of the shell, without the soft parts. Hence many fossil and some recent species have possibly been reversed in the descriptions. Thus many of the palæozoic species referred to *Nucula* are described as having the beaks turned forward, the larger end of the shell being considered posterior; but in modern *Nuculæ*, the beaks turn backward, and the shorter end is posterior. Many of the deep sea species with small, thin shells show no distinct muscular nor pallial scars, which increases this difficulty. When a differentiated external ligament is present, we have assumed that it is posterior to the beaks (opisthodetic),

though a narrow extension usually runs under and forward of the beaks in a groove. When the shell of a dimyarian bivalve gapes posteriorly, the existence of a siphon may generally be assumed; for otherwise the internal soft parts would be exposed to enemies. The existence of a posterior rostrum or a protrusion of the posterior margin defined by an inferior emargination indicates the existence of a siphon, or at least an anal tube, but these organs may exist without such modifications of the shell. If these rules be applied to palæozoic forms we must conclude that the rostrate and subrostrate forms of *Palæoneilo*, etc., had some sort of a siphon, and therefore were not Nuculidæ, as now restricted.

Family Nuculidæ.

We have included *Nuculina* (D'Orb.) in the Nuculidæ with some doubt, because authors differ as to its structure. It is said that its ligament is wholly external; if so, it should, perhaps, form a distinct subfamily. Its anatomy is unknown. Fischer places it in the Arcidæ, near *Limopsis*, but it has no median ligamental area.

Subfamily Glominæ, nov.

Ligament thick, elongated, attached for most of its length to the inner surface of the posterior hinge-plate and running forward in a narrow groove beneath the beaks, so that its anterior portion is external and the thickened posterior portion is partly internal. No pallial sinus. Animal not known.

This group includes, so far as known, only the genus *Glomus* Jeffreys, which has been referred by several writers to the Arcidæ, and by others to the Ledidæ, from both of which it differs widely. Its relations to the Nuculidæ are somewhat uncertain, owing to our ignorance of the soft parts. In the form and position of the ligament it differs entirely from all other genera of Nuculidæ and Ledidæ.

Glomus Jeffreys. Figures 1, 2.

Glomus Jeffreys, Annals, Mag. Nat. Hist., p. 433, 1876; Proc. Zoöl. Soc. London, p. 573, pl. xlv, figs. 5, 5*a*, 1879; Smith, Report Voy. Challenger, Zoöl., xiii, pp 248–249, pl. xxi, figs. 1–3*b*, 1885.

Shell thin, smooth, sub-equilateral, rounded at both ends, with the beaks turned forward. No lunule nor escutcheon. Hinge with two series of obliquely transverse teeth; a small lateral tooth.

The following are described species:

G. nitens Jeff., *G. Jeffreysi* Smith, *G. simplex* Smith, *G. inæquilateralis* Smith, *G. Japonicus* Smith.

Family LEDIDÆ. Subfamily LEDINÆ.

Leda Schumacher, 1817. Figure 19. Type *L. rostrata* (Mont.).

This genus has been variously extended and restricted by authors, and several subgeneric and sectional groups have been proposed. In the more extended sense it is scarcely capable of a definition that will distinguish it from *Yoldia*, etc.

We propose, therefore, to restrict it to the typical species, such as *L. cuspidata* Gld., *caudata* Donovan (fig. 19), *pernula* (Müll.), *tenuisulcata* (Couth.) and many others, closely related. These have a long, tapered, bicarinate rostrum, and well-developed siphon tubes, partially united. The palpal tentacles are long, flat, tapered, and arise external to the bases of the outer palpi, which are broad, with slender, acute posterior tips.

Ledella, gen. nov. Figures 13, 18. Type *L. Messanensis* (Seg.).

Junonia Seguenza, Nuculidi terziarie merid. d' Ital., R. Accad. Lincei, i, p. 1175, 1877 (not of Hübner).

This group includes a large number of small species, both living and fossil, in which the shell is rather short, usually ovate or swollen, with a small, acute, or subacute, unicarinate rostrum, situated medially or submedially, and defined below by an emargination or undulation in the postero-ventral margin. The postero-dorsal margin is usually convex. The escutcheon or ligamental area is distinctly defined by the carina, but is not sunken. The chondrophore is usually small but distinct. The siphon tubes are separate, at least in some species.

The following species appear to belong here:

L. seminula (Seg.), *L. Messanensis* (Seg.) (fig. 13), *L. Nicotræ* (Seg.), *L. peraffinis* (Seg.), *L. rectidorsata* (Seg.), *L. confusa* (Seg.), *L. solidula* Smith, *L. semen* Smith, *L. confinis* Smith, *L. inopinata* Smith, *L. prolata* Smith, *L. ultima* Smith, and *L. parva* V. & B.*

Portlandia Morch. Type *P. arctica* (Gray), 1819=*Leda Portlandica* (Hitch.).

We consider this a distinct genus, but would restrict it to the original type. In many respects this genus is intermediate between *Leda* and *Yoldia*. In its closed shell, definite rostrum,

* *Ledella parva*, sp. nov. Figure 18.

Shell minute, smooth, narrow ovate, inequilateral, obtusely rounded anteriorly, slightly rostrate posteriorly with a slight postero-ventral emargination; the short rostrum subtruncate at tip and defined by an inconspicuous ridge. Umbos somewhat swollen, beaks a little prominent and turned slightly backward. Hinge-plate strong with fifteen anterior and nine posterior teeth. Chondrophore rather small, triangular with a distinctly projecting inner margin. Length, 3mm; height, 2mm.

Station 2689, off Martha's Vineyard, in 525 fathoms, 1886.

etc., it agrees more nearly with the former, but in general outline, with the latter.

Yoldia Möller. Figures 12, 16. Type *Y. hyperborea* Torrell.

We propose to restrict this genus to the typical forms, such as *limatula* (Say) (fig. 12), *sapotilla* (Gld.) (fig. 16), *myalis* (Couth.) and many closely allied foreign species.

These have a nearly smooth, compressed, lanceolate, gaping shell, more or less prolonged and tapered posteriorly, with a poorly defined wide rostrum, generally without carinations. The external ligament is marginal, feebly developed, continuous under the beaks, and not much differentiated from the general epidermis. The chondrophore is large, concave, and projects within the margin. The pallial sinus is large and deep. The siphon-tubes and posterior pallial tentacle are long. The palpal tentacles are long and tapered; in life they may extend nearly to the end of the expanded siphon.

Orthoyoldia, gen. nov. Type *Orthoyoldia scapina* (Dall).

Shell oblong, gaping, blunt or rounded at both ends, without distinct rostrum; no carina. Pallial sinus large and broad. Teeth numerous in both series. *O. scapina* (Dall), from off Brazil, and *O. solenoides* (Dall), from the West Indies.

Megayoldia, gen. nov. Figure 17. Type *M. thraciæformis* (Storer).

Shell large, compressed, gaping, with a very short, blunt, indefinite, postero-dorsal rostrum. A low radial ridge, ends in a postero-ventral marginal lobe. A well defined but thin external marginal ligament extends both before and behind the beaks, anteriorly with a supramarginal furrow.

The chondrophore is remarkably large and strong, concave, striated within, and projects much within the margin of the hinge-plate. The pallial sinus is large and deep.

The postero-ventral margin of the mantle forms a pouch-like protrusion, corresponding to the radial ridge. The siphon tubes are long and united; the posterior pallial tentacle is long and slender. The palpi are very large. The palpal tentacles originate from the body wall at the base of the outer palpi; they are long and thick, with a large furrow on one side.

Yoldiella, gen. nov. Figures 3, 4, 11, 14. Type *Yoldiella lucida* (Loven).

This group includes a large number of small, mostly deep-sea species, with glossy, iridescent, ovate, and usually wedge-shaped shells, nearly always having a slight postero-ventral sinuosity,

which feebly defines an obscure, blunt, rostral region, without any definite carination. The shells do not gap, but close tightly, except that at the rostral angle of some species there may be a slight divergence. The internal cartilage, which is often relatively large, occupies a simple notch, which interrupts the hinge margin more or less completely and generally shows externally in a dorsal view; the notch usually terminates within on the inner or inferior surface of the hinge plate and is often bounded within by a slight ridge. A weak external ligament is present on the postero-dorsal margin. A relatively small, pallial sinus has been observed in several of the species, but is usually indistinct. The siphon tubes, as observed in a few of the species, are slender and united for more than half their length.

The following are some of the species:

Y. lucida (Lovén), *Y. inflata* V. & B.,* *Y. Jeffreysi* (Hidalgo), *Y. lenticula* (Möller), *Y. frigida* (Torell), and *Y. Hoylei* (Smith).

Microyoldia, gen. nov. Figures 5, 6. Type *M. regularis* (V.).†

Shell small, tightly closed, veneriform, with the anterior end the shorter, with the beaks turned forward. A posterior marginal ligament in a distinct groove, continued under the beaks. Hinge-plate and teeth rather strong; anterior series of teeth the shorter, forming a marked angle with the posterior series. Internal cartilage supported by a relatively large and strong chondrophore, placed on the surface of the hinge-plate, distinctly behind the beaks and at the proximal end of the posterior series of teeth. Pallial line indistinct.

The curious little shell for which this genus is proposed is remarkable for its form and the internymphal position of the cartilage and chrondrophore, as well as for its few short teeth. If we are correct in our conclusions as to the anterior and posterior ends, the beaks turn forward as in *Tindaria*.

Subfamily Malletinæ.

Malletia Desmoulins (restricted). Figure 9. Type *Malletia Chilensis* Desmoulins.

We propose to restrict this genus to those species having a nearly smooth, somewhat compressed, oblong or elliptical shell,

* *Yoldiella inflata*, sp. nov. Figures 3, 4, 11.

Shell small, smooth, shining, somewhat iridescent, swollen, rather short, subovate, inequilateral, broadly rounded anteriorly, broad and obtusely subtruncated posteriorly, with a slight angle at the upper extremity. Umbos well-rounded; beaks small, appressed to the margin. External ligament delicate. Hinge-plate moderately broad, with nine to eleven anterior and about ten posterior teeth, separated by the small cartilage pit. Epidermis pale olive-yellow or straw color.

Length of one of the largest specimens, 6^{mm}; height, 4·5^{mm}; thickness, about 3^{mm}.

Found at about twenty stations from south of Georges' Bank to Cape Hatteras, N. C., in 516 to 1608 fathoms, 1883–1886.

† Verrill, Trans. Conn. Acad., vi, p. 228, 1884.

blunt posteriorly, without any definite rostrum or carination. The carinated and rostrated species that have been placed in it will thus be referred to *Neilo* H. and A. Adams. The siphon tubes are long and united nearly to the tips.

The following are some of the known species:

M. Chilensis Desmoulins (Type), *M. obtusa* (Sars) Mörch, *M. pallida* Smith, *M. arrouana* Smith, *M. Dunkeri* Smith, and *M. Bellardii* Seguenza

The subgenus *Pseudomalletia*, proposed by Fischer for *M. obtusa*, was based on an erroneous description of the siphon tubes.

Neilo Adams. Type *N. Cumingii* Adams.

The type-species of this genus has an oblong shell, with a straight postero-dorsal margin and a well defined rostrum, bounded beneath by a pronounced furrow and a marginal indentation, while more ventrally the margin protrudes somewhat, the pouting of the margin corresponding with special lobes of the margin of the mantle. The type-species is concentrically grooved, but *N. goniura* Dall is smooth or nearly so.

Neilonella Dall. Figures 7, 8, 22. Type *N. corpulenta* Dall.

Saturnia Seguenza, Nuculidi terziarie merid. d'Ital., R. Accad. Lincei, i, p. 1178, 1877 (non Schrank, 1802).

Leda (section *Neilonella*) Dall, Bull. Mus. Comp. Zoöl., ix, p. 125, 1881; xii, p. 254, 1886 + *Saturnia*, op. cit., p. 253.

Shell ovate, with both ends obtuse; the posterior end somewhat longer than the anterior, without any distinct rostrum or carina. Exterior usually concentrically grooved. Ligamental area not defined. Beaks usually prominent and turned inward and slightly backward. External ligament well-developed; it extends under and before the beaks in a distinct groove, more prominent behind. Internal cartilage very minute or nearly abortive, occupying a slight notch in the medial dorsal margin, external to the series of teeth, which proximally become minute and are interrupted only by a small, thin edentulous space. Pallial sinus small. Siphon tubes short. Labial palpi large, broad, crescent-shape, with long tentacular appendages. Gills small, triquetral.

The following species appear to belong here:

N. corpulenta Dall (type), *N. quadrangularis* (Dall), *N. sericea* (Jeffreys), *N. pusio* (Phil.), and *N. subovata* V. and B.*

* *Neilonella subovata*, sp. nov. Figures 7, 8, 22.

Yoldia sericea Jeff. var. *striolata* Verrill, Trans. Conn. Acad., vi, p. 226, 1884.

Shell somewhat swollen, subovate, sculptured with regular concentric sulcations and ridges, usually faint or obsolete posteriorly, and with a number of faint radiating striæ posteriorly. Beaks curved strongly inward and a little backward. Hinge margin rather strong, the series of teeth interrupted by a small edentulous space; eleven or twelve anterior and fifteen or sixteen posterior teeth. External ligament well-developed, dark brown, conspicuous behind the beaks, and extending a

Subfamily TINDARINÆ, nov.

Cucullellinæ (pars) Fischer, Man. Conch., p. 981. *Ctenodontidæ* Dall (pars), Trans. Wagner Free Inst., iii, p. 515, 1895.

In this group the shell is short-ovate or veneriform, with the posterior end the longer. The beaks turn forward. The internal cartilage is wanting. The external ligament is well-developed and prominent. The teeth are numerous, v-shaped, the two series are frequently continuous proximally. There is neither pallial sinus nor true siphons. The mantle is broadly open ventrally, but there is a separate anal or efferent orifice, surrounded by small sense papillæ. The palpi are large, with long slender appendages. Foot with a large, terminal, crenulated disk.

This group agrees with *Malletinæ* in having no internal cartilage, but there are, in the latter, well-developed siphons and a pallial sinus.

Numerous Palæozoic species referred to the genus *Palæoneilo* probably belong to or near this group. Some of the species* from the American Devonian rocks can hardly be distinguished from *Tindaria* by any important structural characters. It is probable that *Nuculites* and several related genera also belong to this division, for they have an external cartilage and no chondrophore. In these genera the plain transverse teeth are very numerous and more simple than in the modern genera, seldom showing any trace of the acute v-shaped form.

Mr. Dall has proposed the family *Ctenodontidæ* to include the extinct genera above named and others, but it is doubtful whether *Ctenodonta* itself belongs here. Zittell and others refer it to Arcidæ.

Tindaria Bellardi. Figures 10, 20, 21. Type *T. arata* Bellardi.

Several recent writers on these shells have regarded *Tindaria* as a subgenus of *Malletia*. In reality they form two widely diverse genera. In typical *Tindariæ* the shell is swollen, ovate, short, or subcordate, without any rostration, and with prominent umbos, with the beaks turned forward. In fact, the shells may be described as veneriform. The surface is usually concentrically grooved. The series of teeth are often continuous medially. There is no pallial sinus.

The following are some of the known species:

T. arata Bellardi, *T. solida* Seguenza, *T. cytherea* Dall = *T. veneriformis* Smith, *T. amabilis* Dall, *T. virens* Dall, *T. acinula*

little in front of them. Cartilage minute, marginal. Epidermis without much luster, either greenish yellow or light straw-color. Muscular impressions faint; sometimes a distinct angular pallial sinus is visible.

Length, 6·5^{mm}; height, 4·6^{mm}; thickness, about 3·5^{mm}.

Found at many stations from off George's Banks to Cape Hatteras, in 125 to 1731 fathoms, 1883–1887.

* For examples see *P. constricta* Hall, *P. plana* Hall in Palæontology of New York, v, pt. 1, pp. 333, 334, pl. xlviii, figs. 1–28, 1885.

Dall, *T. cuneata* Smith = *T. Smithii* Dall, and *T. callistiformis* V. and B.* All except the first two are from American waters.

Subgenus *Tindariopsis*, nov. Type *T. agathida* (Dall).†

This division is proposed for those species which have a short rostrum, defined by a radial ridge and a furrow. The type has a well-marked dorsal ligamental furrow and a small notch or "socket" under the beak for a specialized part of the ligament.

It is uncertain whether it has a siphon and pallial sinus. In case these are present, it should form a distinct genus and be referred to Malletinæ.

Analytical table of recent subfamilies, genera, and subgenera of Ledidæ and Nuculidæ here adopted.

A. Shell not gaping, short-ovate, subtrigonal, or rounded; posterior end without a rostrum; beaks usually curved backward; no siphon tubes nor pallial sinus. Nuculidæ d'Orb.

B. Shell more or less trigonal, usually oblique; posterior end usually shorter; beaks turned backward.....Nuculinæ.

c. Teeth numerous, transverse, v-shaped, forming two convexly arched or angulated series; a distinct median chondrophore; no lateral teeth.....Nucula Lam.

cc. Teeth few, not forming long series; a long lateral tooth in each valve; no median chondrophore.....Nuculina.

BB. Shell rounded, nearly equilateral; beaks turned forward; teeth oblique, in two series; ligament in an elongated posterior internymphal groove.....Glominæ, nov.

AA. Shell ovate, oblong or lanceolate; posterior end generally the longer and usually more or less rostrated; siphon tubes and pallial sinus generally present.....Ledidæ.

C. Cartilage or resilium present, not closely united with the external ligament.....Ledinæ.

a. Resilium supported by a definite concave chondrophore extending inward to or beyond the inner edge of the hinge-plate.

b. Shell not gaping unless at the end of the rostrum.

c. Shell distinctly rostrated and carinated posteriorly. Leda Schum. (sens. ext.)

* *Tindaria callistiformis*, sp. nov. Figures 10, 20, 21.

Shell small, stout, thick, regularly ovate, sculptured with very regular fine concentric grooves. Umbos swollen, beaks prominent, curved strongly inward and somewhat forward. Hinge-plate with a continuous series of teeth, about eight before and twenty-three behind the beaks. Ligament groove rather deep, submarginal, both before and behind the beaks. Color pale yellowish brown, internally glossy, bluish white.

Length, 8^{mm}; height, 6^{mm}; thickness, about 4·5^{mm}.

One living specimen, station 2566 off Chesapeake Bay, in 2620 fathoms, 1885.

† *Malletia* (*Tindaria*) *agathida* Dall, Proc. U. S. Nat. Mus., xii, p. 252, pl. xiii, fig. 10, 1889.

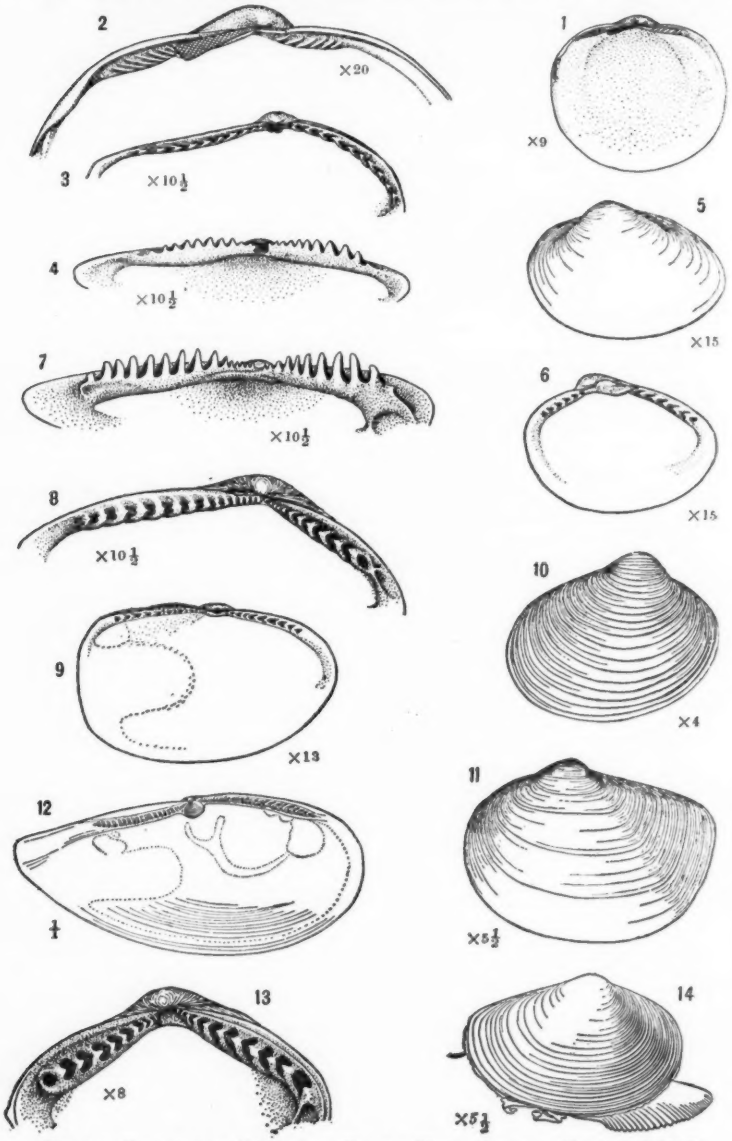


Fig. 1.—*Glomus nitens*, left valve. Fig. 2.—Hinge of same. Fig. 3.—*Yoldiella inflata* V and B., hinge of left valve. Fig. 4.—Profile of same. Fig. 5.—*Microyoldia regularis* (V.) left valve. Fig. 6.—The same, right valve. Fig. 7.—*Neilonella subovata* V. and B., hinge of left valve, profile. Fig. 8.—The same, front view. Fig. 9.—*Malletia obtusa* left valve. Fig. 10.—*Tindaria callistiformis* V. and B., right valve. Fig. 11.—*Yoldiella inflata* V. and B, left valve. Fig. 12.—*Yoldia limatula*, left valve. Fig. 13.—*Ledella messanensis* variety, left valve. Fig. 14.—*Yoldiella lucida*, from life, soft parts partly expanded. Figs. 12 and 14 are by J. H. Emerton; all others by A. H. Verrill.

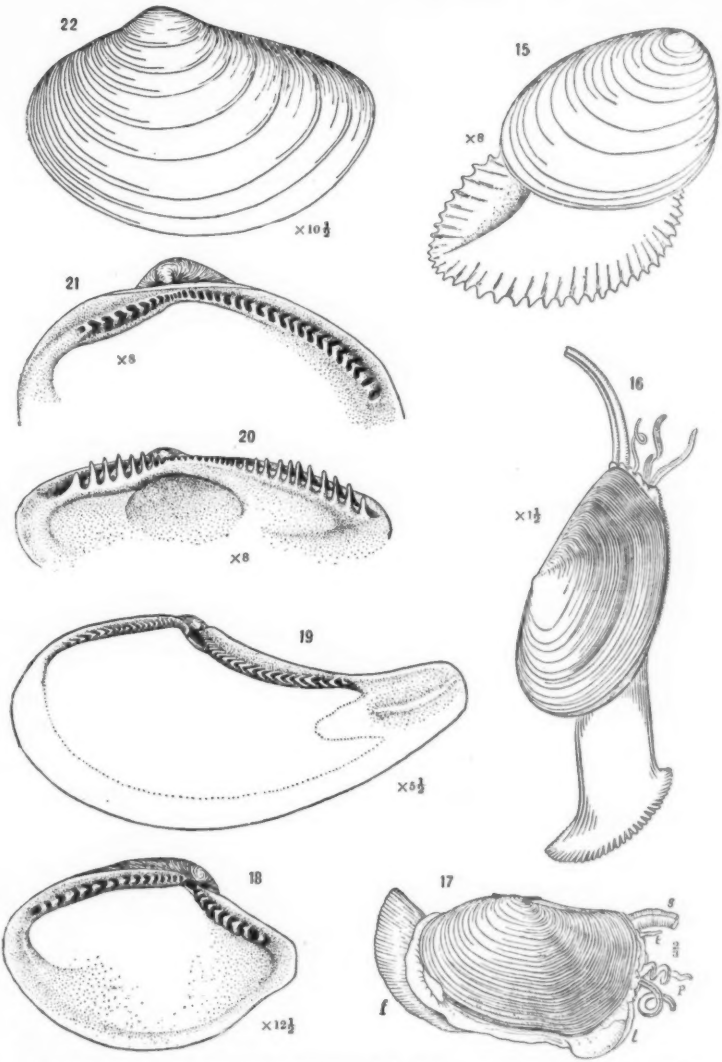


Fig. 15.—*Nucula proxima*, with expanded foot. Fig. 16.—*Yoldia sapotilla*, from life, with expanded soft parts. Fig. 17.—*Megayoldia thraciæformis*, from life; *f*, foot; *l*, pallial pouch; *t*, pallial tentacle; *p*, palpal tentacles; *s*, siphon. Fig. 18.—*Ledella parva* V. and B, right valve. Fig. 19.—*Leda caudata*, right valve. Fig. 20.—*Tindaria callistiformis* V. and B., hinge of right valve, nearly in profile. Fig. 21.—The same, front view. Fig. 22.—*Neilonella subovata* V. and B., left valve. Figs. 15, 16, 17 are by J. H. Emerton; all others by A. H. Verrill.

d. Shell elongated and tapered posteriously, rostrum long, bicarinate, blunt, ligamental area or escutcheon long and well-defined; pallial sinus and siphon tubes developed ..... Leda (sens. rest.)

dd. Shell shorter, swollen, ovate or oblong, posteriorly not much elongated; rostrum short, usually acute, unicarinate.

e. Shell ovate, rostrum small acute; ligamentary area or escutcheon distinctly bordered by a carina.

f. Rostrum short, sub-acute, sub-median, defined below by a ventral-sinuosity or emargination.
Ledella, nov. = Junonia Seguenza.

ff. Rostrum short, dorsal, not defined below by a ventral sinuosity; postero-dorsal margin concave; escutcheon sunken ..... Jupiteria Bellardi.

ee. Shell oblong, angular, subtruncate, rostrum short, angular, dorsal, defined below by a marginal sinuosity; escutcheon well defined ..... Portlandia Mörch.

cc. Shell not rostrated, small, ovate or elliptical, rounded at both ends, anterior end the shorter, no carina, lunule, nor escutcheon; cartilage posterior, internymphal.
Microyoldia, nov.

bb. Shell oblong or lanceolate, compressed, nearly plain, more or less gaping at both ends; rostrum not well defined; pallial sinus large and broad; tubes long, united.

g. Teeth transverse, v-shaped, numerous, in two long series; chondrophore large, concave, projecting strongly inside the hinge-plate ..... Yoldia Möller (sens. ext.)

h. Shell large, compressed, rounded anteriorly, broadest posteriorly with a postero-ventral protrusion and radial ridge; rostrum short, broad, poorly defined; external ligament well-developed, prominent both sides of the beaks, occupying a continuous furrow; no lunule nor escutcheon ..... Megayoldia, nov.

hh. Shell lanceolate or long-ovate, posteriorly narrowed and somewhat elongated, more or less sinuous below; rostrum slightly defined, smooth or slightly carinate; external ligament feebly developed .. Yoldia (sens. rest.)

hhh. Shell oblong, smooth, plain, blunt and rounded at both ends, without any distinct carina, sinuosity or rostrum.
Orthoyoldia, nov.

hhhh. Shell thin, compressed, narrow lanceolate or long elliptical, nearly equilateral, and gaping at both ends.
Adrana H. and A. Ad.

gg. Shell thin, oblong, inequilateral, blunt at both ends, not rostrated nor carinated; teeth few, lamellar, very oblique. Type *S. fragilis* Jeffreys ... Silicula Jeffreys.

aa. Shell small, nearly plain, not much rostrated nor carinated; cartilage without a prominent chondrophore, situated in a notch in the hinge-margin, interrupting the series of teeth.

l. Teeth v-shaped, numerous in both series.

m. Shell oblong or subovate, blunt posteriorly, with a slightly sinuous margin, sometimes subrostrate, not carinate. Yoldiella, nov.

mm. Shell regularly ovate, rounded at both ends, not sinuous, nor carinate, (?) no pallial sinus .....Sarepta A. Ad.

ll. Shell short-ovate, not sinuous nor angulated; teeth few, oblique, not regularly v-shaped. Type *P. ovatus* Seguenza .....Phaseolus Seg.

CC. No true internal cartilage; ligament well-developed, often prominent behind the beaks. Beaks usually turned forward.

D. Siphon tubes and pallial sinus present; teeth mostly v-shaped, in two long series, often interrupted by a median edentulous space.....Malletinæ.

o. Siphon tubes long; pallial sinus large; shell elongated, gaping.

p. Shell oblong or elliptical, blunt posteriorly, not distinctly rostrate; series of teeth unequal; those in the anterior series fewer.....Malletia Desm.

pp. Shell long-ovate or oblong, broadly angulated and sinuous posteriorly; distinctly rostrate and carinate; two series of teeth nearly equal ..... Neilo H. and A. Ad.

oo. Siphon and pallial sinus small, shell ovate, not gaping; a rudimentary marginal resilium.....Neilonella Dall.

DD. Shell short-ovate or subcordate, closed at both ends; umbos prominent; ligament entirely external; series of teeth generally continuous.....Tindarinæ, nov.

s. Shell regularly ovate, grooved, without rostrum or carina; beaks turned forward; no pallial sinus. Tindaria Bellardi.

ss. Shell ovate, with a distinct posterior sinuosity and a short rostrum.....Tindariopsis, nov.

ART. VI.—*An Experiment with Gold;* by M. CAREY LEA.

SOMETIME since I had occasion to reduce a number of gold solutions and used for this purpose sodium hypophosphite. The solutions all acted in the usual way with one exception: in this the liquid turned deep emerald green. This condition lasted about ten minutes and then the metal was precipitated.

I have since determined the conditions under which this appearance takes place and its explanation.

A weighed quantity of pure gold was dissolved and the solution was evaporated to dryness twice. The chloride was then dissolved in water in the proportion of 1 gram of metallic gold to each 10^{cc} of solution. A 10 per cent solution of sodium hypophosphite was also made. These solutions mixed in various proportions produced the green solution; perhaps the most satisfactory result was obtained as follows:

Of the hypophosphite solution 15^{cc} are to be placed in a beaker and 1^{cc} of the gold solution is to be added and then one drop of sulphuric acid. As soon as the solution begins to darken a little, which will be in from two to four minutes, 30^{cc} of water are to be added without delay. The solution presently assumes a deep green color, remaining quite transparent. By slow degrees it becomes less clear. If filtered at the end of an hour the filtrate will either be yellow or green; if yellow it soon turns green, remaining for some time transparent; and this may be repeated several times.

One explanation presented itself—that there might be present in a state of fine division the olive green oxide of gold Au_2O, described by Prat.* But in the filtrations above referred to there is left on the filter an infinitesimal quantity of a blueish black substance which is not an oxide but metallic gold.

The green color of the liquid is, therefore, due to the presence of a small quantity of gold in its blue form in a state of very fine division, which together with the yellow of the undecomposed solution gives the effect of green.

If when the solution becomes slightly troubled, instead of filtering it is left to itself for a few minutes, the sides of the beaker will receive a deposit of gold, yellowish brown by reflected light but clear blue by transmitted.

* Roscoe & Schorlemmer, vol. ii, part 2, page 377.

ART. VII.—*Note on a new Meteorite from the Sacramento Mountains, Eddy Co., New Mexico;* by WARREN M. FOOTE. With Plates I and II.

ON nearing Fort Stanton, Arizona Territory, while on a westward journey in 1876, Mr. M. Bartlett of Florence, A. T., saw a meteor pass through the heavens in a southerly direction and fall, with a report like that of a cannon, on the east side of the Sacramento Mountains.

The above account was given by Mr. Bartlett to Mr. C. R. Biederman, and to the latter gentleman is due the credit of securing the specimen to science and furnishing the historical data here given.

Continued inquiry in the Pecos country was fruitless until by chance a small sample of native iron was presented to Mr. Biederman, for assay, and proving to be meteoric, led to the locating of the mass through the first finder, a shepherd, named Beckett.

The latter, in a sworn statement, says that he found it while herding in the lower foot-hills of the Sacramento Mountains, Eddy Co., N. M., about twenty-three miles southwest of a place called Badger. It rested on top of a limestone hill, where it had made a depression, and was partly buried. He could find no other pieces. Mr. Biederman, heading a search party, found the mass at the place indicated, and with much labor dragged it six miles over the desert to a wagon road. A long search was made by the party, but nothing else could be found. It is complete, save for about 500 grams of fragments, broken off by Beckett, and a piece of 1500 grams sawed off after it came into the possession of the firm of Dr. A. E. Foote. Its appearance indicates that no rupture occurred through an explosion during its flight nor by the force of the fall. The small fragments mentioned were employed in analysis and the making of a knife.

Description of the mass.—It is a typical example of the class of siderites, weighing complete about two hundred and thirty-seven kilograms, with general dimensions of about 80x60x20 centimeters. The exterior exhibits in a splendid manner the characteristic markings of meteoric iron. On the flat side, shown in Plate I, are two cup-shaped pits of 10 to 12 centimeters diameter which constitute a remarkable feature; the smaller depressions or "thumb-marks" of 3 to 4^{cm} diameter, which cover the remainder of the surface, are also reproduced in minute detail.

At the point where the fragments were removed the octahedral cleavage and lines of crystallization are noticeable to a

degree rarely seen in iron. It is, however, on the etched surface prepared through treating a polished slab with dilute nitric acid, in the usual manner, that the beauty of the crystalline structure is best seen. In this respect it ranks among the finest of recorded irons, the Widmannstätten figures being exceptionally regular and distinct. The accompanying print (Plate II) was made directly from the etched surface. The broad bands of kamacite are symmetrical, the prominence of the interlacing of shining white threads of the niccoliferous iron being especially remarkable, and distinguishing it from the El Capitan meteoric iron, weighing about 28 kilos, and found* in 1893 about ninety miles north of the Sacramento range. In the latter iron the percentage of iron is less and nickel greater, phosphorous also being present. For a careful quantitative analysis the writer is indebted to Mr. J. Edward Whitfield (with Booth, Garrett & Blair, of Philadelphia), who obtained the following results:

Iron	91·39	per cent.
Nickel	7·86	"
Cobalt	·52	"
	99·77	

The mass is perfectly preserved, there being no sign of disintegration or exudation of lawrencite. The sawing done shows it to be quite soft and generally homogeneous. The entire lack of surface alteration proves that it fell at a comparatively recent date, and leads to the conclusion that it is the meteor seen to fall by Mr. Bartlett, whose account led to the discovery.

Philadelphia, Dec. 15th, 1896.

* Prof. E. E. Howell, this Journal, vol. l, p. 253.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Absorption Spectra of Iodine and Bromine solutions at Temperatures above the Critical Temperature of the Solvent.*—It is well known that the absorption spectrum of iodine in carbon disulphide consists of a narrow band in the red and a broad one in the violet, while that of iodine vapor consists of numerous fine lines. Wood has investigated the question whether a rise of temperature will convert the absorption spectrum into the line spectrum, by heating solutions of iodine in varying quantities of carbon disulphide in closed tubes to above 300°, the concentration of the iodine being varied until the line spectrum becomes visible. At this point the density of the carbon disulphide vapor and the concentration of the iodine were calculated and the results plotted. In the case of iodine the numbers obtained gave a curve consisting of two consecutive straight lines making an angle with one another, while the results of similar experiments with bromine gave a curve concave to the axis representing the concentration of the bromine. The ratio of the content of bromine to that of iodine at similar solvent density varied from 6·1 to 9·4 and increased with the concentration. The author points out the analogy between these results and those obtained by Hannay and Hogarth for solutions of solids at temperatures above the critical temperature of the solvent.—*Zeitschr. physikalische Chem.*, xix, 689–695, May, 1896. G. F. B.

2. *On Boiling Points in a Crookes Vacuum.*—Krafft and Weilandt have studied the effect of very high exhaustions upon the boiling point of several organic substances. The pump used was that of v. Babo, a combination of the Bunsen water-pump with the mercury pump of Sprengel, working automatically and exhausting even a large vessel in a quarter to half an hour, so that a mercury manometer shows no difference of level on the two sides. To the distillation apparatus was attached a Hittorf tube, so that when the induction current was passed between its terminals the production upon the glass of the well known green fluorescence indicated approximately a vacuum of one millionth of an atmosphere. The substance was heated in a flask having a capacity of about 15^{cc}, which formed with the receiver a single piece. It was connected to the pump and the Hittorf tube by a ground joint, the thermometer passing through a rubber stopper in the neck of the flask. When in use, the receiver was covered with filter paper on which lumps of ice were placed. The substances experimented on, of course, were only those which at this temperature have no vapor-pressure; such as the higher paraffins, cetyl alcohol, chloride and iodide; the higher fatty acids and their amides; the higher acids of the oleic and oxalic series; alkylbenzenes of high molecular mass; mixed aliphatic-aromatic ketones of high molecular mass;

and sulphobenzide, dinaphthyl sulphides and sulphone. In all these cases it was found that a large lowering of the boiling point was brought about by the last small reduction of pressure; the difference in the boiling point at 15^{mm} pressure and in the Crookes vacuum varying from 70·5° in the case of cetyl alcohol, 78° in that of stearic acid and 98° in heptacosan $C_{27}H_{56}$, to 102° in the case of octadecylbenzene and 105° in that of pentadecylxylylketone.—*Ber. Berl. Chem. Ges.*, xxix, 1316, May, 1896. G. F. B.

3. *On the Formation of Persulphuric Acid.*—The relation between the concentration of the sulphuric acid subjected to electrolysis and the amount of persulphuric acid formed, has been studied by Elbs and Schönherr. They determined the persulphuric acid by pouring 5 to 10^{cc} of the liquid into 200 to 300^{cc} of cold water, adding a known quantity of ammonium ferrous sulphate and then titrating back with potassium permanganate. They find that very little persulphuric acid is formed when the density of the sulphuric acid used is below 1·2; the maximum yield being obtained when this density is 1·35 to 1·5. Since the quantity of persulphuric acid produced is increased by an increase in the strength of the current, it must be formed by the union of the HSO_4 ions at the anode and is not due to oxidation: since in the latter case the amount formed would decrease rather than increase with the current strength. If the electrolyte be too concentrated, the yield is lessened, because (1) the concentrated acid is a bad conductor, (2) the molecules of $H_2S_2O_8$ when produced in a strong acid are not as free to move as in the more mobile dilute acid, and therefore, remaining longer at the anode, are to some extent decomposed, and (3) with concentrated acid, greater heat is developed and a greater number of molecules is thereby destroyed. Increase of temperature diminishes the amount of persulphuric acid formed, it being decomposed at 60° as rapidly as it is produced. If the acid be moderately dilute and the current strong, it is soon interrupted. On warming, however, the electrolysis begins anew, the interruption being caused by the formation of a non-conducting coating of $H_2S_2O_8$ at the anode. If the dilute acid have a density less than 1·3, no hydrogen peroxide, practically, is produced by the decomposition of the persulphuric acid. It increases, however, as the strength of the electrolyte increases. Persulphuric acid may be diluted with 50 times its volume of cold water without decomposition.

Elbs demonstrates the formation of persulphuric acid and of its potassium salt, by filling a wide test tube with the electrolyte, placing in it an anode consisting of a platinum wire enclosed in a glass tube for the greater part of its length, and a kathode made of a platinum ring. The bubbles of gas evolved are collected in a wider tube surrounding the anode and are thus prevented from reaching the cathode. The whole apparatus is placed in a beaker of cold water and a current is passed through it whose density is 100 amperes per square meter of anode surface. If the sulphuric acid have a specific gravity of 1·4, persulphuric acid can

be detected at the anode in five minutes. Using a cold saturated solution of potassium sulphate in dilute sulphuric acid, a considerable amount of crystallized potassium persulphate may be obtained in 10 minutes. A longer time is required for the formation of the ammonium salt.—*Chem. Centr.* 1895, i, 591, ii, 476; *J. Chem. Soc.*, lxx, ii, 519, September, 1896. G. F. B.

4. *On the Reaction of Silver oxide upon Hydrogen Peroxide.*—The equation expressing the decomposition of silver oxide by hydrogen peroxide was for a long time believed to be the following:

$$Ag_2O + H_2O_2 = Ag_2 + H_2O + O_2.$$

Berthelot, however, substituted for this the more complex equation:

$$(Ag_2O)_4 + (H_2O_2)_2 = (Ag_2)_2 + (Ag_2O)_2 + (H_2O)_2 + O_2.$$

Riegler has now studied this reaction more carefully and has come to the conclusion that neither of the above equations correctly represents the actual changes taking place. He therefore substitutes for them the following one:

$$(Ag_2O)_2 + (H_2O_2)_2 = Ag_4O + (H_2O)_2 + (O_2)_2.$$

Subsequently the silver oxide Ag_4O splits up into the oxide Ag_2O and free silver:

$$Ag_4O = Ag_2O + Ag_2.$$

—*Chem. Centr.*, 1895, ii, 545; *J. Chem. Soc.*, lxx, ii, 471, August, 1896. G. F. B.

5. *On Silver peroxynitrate.*—The black deposit which is formed at the anode when a solution of silver nitrate is electrolyzed, and which was first observed by Ritter in 1814, has been investigated by Sulc. The cathode was a platinum dish and the anode a strip of platinum foil cut in the form of a comb and rolled up. The solution contained 15 per cent of silver nitrate and a current of 0·06 ampere was employed, the density at the cathode being 0·0033 ampere per centimeter. After three or four hours, the solution, now contaminated with free nitric acid, was renewed. The crystalline deposit on the anode was removed by means of a glass rod and washed until free from silver. On analysis it gave numbers agreeing with the formula Ag_7NO_{11}. It was in the form of beautiful black octahedra having a metallic luster and a specific gravity of 5·65. In dry air it is fairly stable at the ordinary temperature, but when quickly heated to 155° it evolves oxygen and yields a voluminous dark brown powder. Water decomposes it only slightly, silver nitrate going into solution. When boiled with water for a day and a half, the silver is deposited in the form of a mirror. When boiled with alcohol, aldehyde is formed and a mirror deposited; this mirror being fine if a few drops of ammonia be added. Oxalic acid decomposes it completely with evolution of CO_2; and ammonia, with evolution of nitrogen. Since 1·40, the percentage of nitrogen, corresponds to a percentage of silver as $AgNO_3$ of 12·61, and since this

agrees with the analysis of the residue obtained on decomposing the substance with hot water, the author proposes the formula $(Ag_2O)_3O_5AgNO_3$.—*Zeitschr. anorg. Chemie*, xii, 89–97, Feb., 1896.

MULDER and HERINGA have also examined this substance, preparing it by substantially the same process. The cathode was a liter reservoir of platinum and the anode was a platinum wire, a small glass vessel placed beneath serving to collect the black compound as it formed. In one series of experiments the solution was maintained neutral by means of silver carbonate, and in the other it was not neutralized. According to these authors, the substance obtained is liable to spontaneously decompose at the ordinary temperature, evolving oxygen. The analysis of the black compound obtained from concentrated solutions points to the composition $(Ag_2O)_3O_5AgNO_3$; or perhaps $(Ag_3O_4)_2AgNO_3$ or $(Ag_2O_2)_3AgNO_3$.—*Rev. Trav. Chim.*, xv, 1–51, 1896; *J. Chem. Soc.*, lxx, ii, 561, October, 1896. G. F. B.

6. *On a new Hydrocarbon*, $C_{14}H_{12}$.—By dropping benzyl-ethyl ether into a flask provided with a return condenser and containing a mixture of phosphoric oxide and benzene, SCHICKLER has obtained a new hydrocarbon. At first the mixture is heated on the water-bath, but afterward, as the reaction becomes active, it is cooled. Ethylene is evolved and the liquid shows blue fluorescence. On distilling off the benzene and fractioning the residue, a clear, colorless aromatic liquid is obtained which can be crystallized by cooling, thus forming thick hard prisms, having the formula $C_{14}H_{12}$ and giving an odor like that of benzyl-ethyl ether. It fuses at 27°–28°, boils at 253°–254°, and is soluble in all the usual solvents, these solutions showing no fluorescence. It yields three nitro-compounds, two of which are crystalline and appear to be di-nitro derivatives fusing at 181° and 108° respectively, while the third melts at 75° and does not crystallize. It is dissolved and sulphonated by strong sulphuric acid.—*J. pr. Chem.*, II, liii, 369–374, May, 1896. G. F. B.

7. *On Fractional Distillation of acids of the Acetic series.*—SOREL has applied to mixtures of the first four acids of the acetic series with water, the method of fractional distillation used by him with aqueous alcohol, the composition of the vapor at each instant being calculated from the curve representing the variations in the composition of the liquid in the retort. He finds that in dilute solutions the proportion of acid in the vapor is higher the greater the molecular mass of the acid. When the concentration increases the reverse is the case, the proportion being lower the greater the molecular mass. Hence mixtures of propionic or butyric acid and of water, of a certain composition distil unchanged as if they were definite hydrates. Moreover, butyric acid shows a peculiar phenomenon in that with any proportion of acid between 24 to 34 per cent, the composition of the distillate is independent of the composition of the liquid in the retort; its behavior being intermediate between that of miscible liquids and liquids which are partially or completely insoluble in one another. —*C. R.*, cxxii, 946–948, April, 1896. G. F. B.

8. *Röntgen Rays.*—Mr. John Macintyre in *Nature*, Nov. 18, 1896, gives an interesting account of his experiments with these rays. He obtained lantern slides of X-ray photographs by focusing the shadow on the fluoroscope screen on the ground-glass screen of an ordinary camera. In addition to the reduced picture of the shadow, he obtained also a picture of the brass mountings and lens of the camera. Hence a sufficient number of X-rays had passed through the screen to form a shadow picture of these objects. It appears that we are not utilizing all the X-rays that are ordinarily produced. The author therefore has advantageously employed a large and thick screen in which the crystals of the fluorescent substance are very much coarser than those ordinarily employed. He confirms the report of previous observers on the effect of the Röntgen rays in producing inflammation of the skin. The hand after being long exposed to their effect looks as if it had been sunburned; becomes red and swollen, and the severer effects remain for a fortnight. J. T.

9. *Rotation in Constant Electric Fields.*—In a very extended paper, Quincke gives the results of his observations on the movements of a large number of solid dielectrics immersed in fluid dielectrics, between the plates of a condenser. The constant electric field was obtained by the use of a Planté battery of twelve hundred cells. The author gives a minute description of the method of construction of this battery. He attributes the rotations of the solid dielectrics to the difference between the dielectric constant of the layers of air adhering to the rotating bodies and the dielectric constants of the bodies themselves.—*Ann. der Physik und Chemie*, No. 11, 1896, pp. 417–486. J. T.

10. *Interferential refractor for electrical waves.*—O. Wiedeburg employs an apparatus for obtaining a difference of path which is analogous to that used by Jamin in his interferential refractor. Righi's apparatus for exciting and detecting short wave-lengths of electricity was employed. The author obtained for the index of paraffine, $n=1{\cdot}418$; for that of glass, $n=2{\cdot}63$.—*Ann. der Physik und Chemie*, No. 11, 1896, pp. 498–522. J. T.

11. *The Cadmium normal element.*—In a communication from the Physikalisch-Technische Reichsanstalt, W. Jaeger and R. Wachsmuth give a careful determination of the temperature coefficient of the new Weston cell. They found that the change of electromotive force of the Weston cell, with a change of room temperature of 1° C., was only $\frac{4}{1000}$ per cent, while with the Clark cell it is $\frac{1}{10}$ per cent. In reference to constancy and ease of reproduction it is not inferior to the Clark cell. Its electromotive force is 1·0184 volts. In the Clark element there is sometimes formed a layer of gas over the zinc amalgam, which raises the layer of zinc sulphate crystals, and therefore increases in a marked manner the resistance of the element. Together with this results a change of electromotive force. This defect does not enter in the use of the Weston cell, if the cadmium sulphate is removed by free acid.—*Ann. der Physik und Chemie*, pp. 575–591, No. 11, 1896. J. T.

II. Geology and Mineralogy.

1. *Geological Survey of Canada, Annual Report.* Vol. vii, for 1894. G. M. Dawson, Director. Ottawa, 1896. — This volume includes eight special reports and accompanying maps (556, 557, 567, 571, 561, 562, 563); besides the Director's summary report of the operations of the survey for the year 1894, Dr. G. M. Dawson contributes a report on the area of the Kamloops map-sheet of British Columbia; R. G. McConnell one on an Exploration of the Finlay and Omenica rivers; D. B. Dowling on the country in the vicinity of Red Lake and part of Berens river, Keewatin; R. W. Ells on the southwest sheet of the "Eastern township of Quebec"; F. D. Adams on the Laurentian, north of the St. Lawrence; R. Chalmers, on the surface geology of parts of the Acadian provinces; G. C. Hoffmann on Chemistry and Mineralogy, and Messrs. Ingall and Brumell on the Mineral Statistics.

2. *Pleistocene glaciation in New Brunswick, Nova Scotia, and Prince Edward Island.*—Mr. Robert Chalmers, in an interesting paper, published in the Annual Report of the Geology of Canada (vol. vii, 1894) on the surface geology of eastern New Brunswick, north-western Nova Scotia and a portion of Prince Edward Island, presents the following conclusions in regard to the glaciation of the region named:

Summarizing the principal facts relating to the Pleistocene glaciation of the region under review, it is found that at the period of the maximum extension of the ice there was a general radial movement from the main *névé*-ground of the north-east Appalachians, northward and eastward into the St. Lawrence Valley, eastward into the south-western embayment of the Gulf of St. Lawrence, south-eastward into the Bay of Fundy and Atlantic Ocean, and southward and south-westward in United States territory.

The St. Lawrence Valley, as far westward as the Thousand Islands, was probably an open channel in the latter part of the glacial period at least, into which ice flowed from the north and from the south.

Although the Appalachian glaciers here referred to were not of great superficial extent, the ice which occupied New England and south-eastern Quebec seems to have been the thickest and heaviest of the Pleistocene glaciers of eastern North America, developed in these latitudes; and the geographical and meteorological conditions favor the view that it was only surpassed in this respect by the great Cordilleran glacier of the west.

In eastern Canada, south of the estuary and Gulf of St. Lawrence, the land ice seems to have consisted of local glaciers, and the different parts which streamed outwards from the central *névé*-grounds have been differentiated and received separate names. That which occupied the Gaspé peninsula and the Notre Dame Range followed the drainage channels, generally speak-

ing, in its descent northward and southward. Along the lower St. Lawrence, the flow was apparently into the open waters of the estuary, while at Gaspé Basin it was eastward directly into the waters of the Gulf of St. Lawrence.

The western part of the Baie des Chaleurs Valley was occupied by a sheet to which the name of the Baie des Chaleurs glacier has been given. South of this and mantling the greater part of the Carboniferous area of New Brunswick and Prince Edward Island, the Northumberland glacier was developed. The great valley of the St. John River and the slopes on either side were occupied by a sheet of ice which has been designated the St. John Valley glacier. The east and south-east termini of these glaciers were attenuated and were not accompanied by moraines. During the epoch of maximum ice accumulation, the coast border was somewhat higher than at present. Subsidence and differential movements set in towards the closing stage of the glacial period, which, in the Carboniferous plain of central and eastern New Brunswick, are evidenced by a number of swerving courses of striæ. These indicate that the watershed between the drainage basins of the St. John River and the rivers falling into Northumberland Strait did not partake of the downward movement of the coast border to such an extent as the latter. The striæ, which show gradually swerving movements on the flat Carboniferous plain, may be taken as evidence that there was no withdrawal of the ice from the region during the whole glacial epoch. Towards the closing stage, the glaciers became smaller and more detached, and floating ice occupied the bays and straits. The markings left by the latter on rock surfaces show that the coastal parts of New Brunswick were then from 75 to 150 feet lower than at present. The country around the Baie des Chaleurs and that on the northern coast border of the Bay of Fundy, seem to have undergone greater differential changes of level than the central Carboniferous area of New Brunswick and Prince Edward Island, the latter area apparently occupying a more stable attitude in regard to crustal oscillations. The subsidence inaugurated then was that which continued into the Leda-clay period.

The peninsula of Nova Scotia was glaciated by land ice which gathered upon its surface, and probably by floating ice in the coast districts at a subsequent stage.

A local glacier seems to have accumulated around the head of Chignecto Bay and upon the isthmus of the same name, in the early stage of the Pleistocene, which has been called the Chignecto glacier. Floating ice has also glaciated the isthmus at a later date.

On the Magdalen Islands no evidences of Pleistocene ice-action, or of the occurrence of boulder-clay, were observed; on the contrary, the rock surfaces are everywhere masked with a covering of their own débris.

The cause or causes of the glacial period, or rather of the

existence of sheets of land ice in these latitudes in Pleistocene times, cannot be discussed here. But it may be remarked that the tendency to eliminate cosmic influences and attribute the refrigeration of the northern part of this continent to geographical or terrestrial causes, characteristic of later studies respecting glacial phenomena, does not seem, so far, to throw a great deal of light on the question, and may after all be only a partial view. If the Glacial Period be wholly due to terrestrial causes, the fact that such causes must be largely of a local character appears to have been overlooked; for it is not probable that these causes would act synchronously in the whole arctic and north temperate zones as far south as the limits of the glaciated belt. That changes in the elevation of the land, changes in the distribution of land and water, changes in the atmospheric and oceanic currents, a greater or less amount of moisture and precipitation than what now obtains, etc., are, taken together, sufficient to bring about a glacial epoch, such as the phenomena indicate must have existed in Pleistocene times, may be seriously doubted. If it were attempted to show that such terrestrial conditions were sufficient to produce a glacial area locally, on one side or the other of the North American continent, for example, or on both sides of the North Atlantic, the hypothesis would seem to be adequate; but these causes, while competent to produce various local oscillations of climate and of glacial conditions, have probably been governed or modified by some general law. It is inferentially certain, therefore, that any hypothesis based on terrestrial conditions which may be propounded will have to include such general or cosmic influences as to affect simultaneously the whole circumpolar and north temperate regions of the earth during Pleistocene time, otherwise glacial conditions cannot have occurred synchronously in both hemispheres, or even on both continents.

3. *Notes sur la flore des couches permiennes de Trienbach (Alsace);* by R. ZEILLER. Bull. Soc. Géol. France, III, xxii, 1894, pp. 163–182, pl. viii, ix.—The material collected at Teufelsbrunnen, in the Forest of Honcourt, Alsace, from a thin series of shales, sandstones and conglomerates, comprising the "Trienbach beds" of Benecke and Van Werveke, has been found by M. Zeiller to include forty species of plants. This flora embraces ferns, *Sphenophylla*, *Calamariæ*, *Cordaiteæ*, *Cycadeæ*, *Coniferæ*, and fruits. While the greater number of the species are found in the upper part of the Carboniferous proper, nearly all are known to pass up into the Permian. On the other hand, several species have been found to be characteristic of the lower portion of the Permian; and the combined evidence leads Prof. Zeiller to correlate the Trienbach beds with those at Cusel, Stockheim, and Igornay, *i. e.*, the basal portion of the Permian.

From the paleontological standpoint this paper is of considerable systematic interest. Thus, from a study of abundant material, M. Zeiller is convinced that *Tæniopteris abnormis, T. fallax, and T. multinervis* are merely variations and phases, due

in part to circumstances of impression, of one species. We apprehend, however, that the last mentioned and later name, adopted by M. Zeiller on account of its priority in respect to correct diagnosis and illustration, will eventually yield to the one proposed by Gutbier, *Tæniopteris abnormis*, though the latter was quite imperfectly described and figured.

Zamites Planchardi, found at Teufelsbrunnen, is compared with the five other species of *Zamites* distinguished by Renault in the Commentry basin, with the result that M. Zeiller is led to place all of them in the new genus *Plagiozamites*, which is characterized by its lanceolate, dentate leaves fixed by thickened, clasping or semi-clasping bases oblique to the plane of the rachis. Though unquestionably a Cycad, it has so much in common with *Noeggerathia* as to bring the author to regard the latter as belonging, not to the ferns, but to the *Cycadeæ*, the view entertained by Brongniart in 1849. In considering *Gomphostrobus bifidus*, a scale bifurcated at the top, to be a seminiferous scale of some conifer, Zeiller differs from Potonié, who regards it as a sporangiferous Psilotaceous leaf. D. W.

4. *Artificial Production of the Mineral Northupite.*—An artificial chlorocarbonate of sodium and magnesium was described in 1893 by Winkler,* who observed it as an incrustation on the inside of iron cooling tubes used in working up saline solutions, rich in magnesium chloride, by the Solvay process. The same salt has recently† been prepared and described by DE SCHULTEN, who made it by adding to a solution of 20 grams anhydrous sodium carbonate and 150 grams sodium chloride in a round bottom flask, a solution of 15 grams of magnesium chloride. The flask was then heated on the water bath for seven to eight hours. The amorphous flocculent precipitate which the solution of magnesium chloride at first produced gradually contracted and transformed itself into brilliant crystals of the chlorocarbonate of sodium and magnesium. The salt has the same chemical composition as the mineral *northupite*, recently described in this Journal,‡ as will be seen from a comparison of the following analyses:

	Salt (Winkler).	Salt (de Schulten).	Mineral (Pratt).	Theory for, $MgCO_3$ Na_2CO_3NaCl.
Na_2O	24·19	25·21	24·90	24·96
MgO	15·07	15·74	16·22	16·09
CO_2	33·73	35·87	35·43	35·41
NaCl	22·59	23·64	23·45	23·54
	2·14 $(NH_4)_2CO_3$			
	1·92 $CaCO_3$			
	·04 FeS			

The physical properties of the salt are identical with those of the mineral.

De Schulten calls attention to the similarity of the salt and the

* Zs. für angewandte Chemie, p. 445, 1893.

† Bull. Soc. Franc. Min., vol. xix, Nos. 5–6, p. 164, 1896.

mineral northupite, of which Foote* had given a preliminary description and states that they are probably identical, which the subsequent quantitative analysis and the determination of the physical properties of the mineral† clearly show. J. H. P.

5. *The genesis of the Talc deposits of St. Lawrence Co., N. Y.*—A paper by C. H. SMYTH, JR., in vol. xvii of the School of Mines Quarterly, gives the results of the author's minute study of the talc deposits of St. Lawrence Co., in northern New York. He concludes that the talc is doubtless pseudomorphous, and that the original minerals were tremolite and enstatite, to which it owes its common fibrous character. He recognizes three distinct stages in the origin of the deposits: first, the formation of an impure siliceous and magnesian limestone; second, the conversion of this into enstatite and tremolite schist by metamorphosis; third, the change of this schist into talc by the action of water charged with carbon dioxide.

6. *A Handbook of Rocks for use without the Microscope;* by JAS. F. KEMP. 8°, 176 pp. (Pub. by author, 1896.)—This little handbook will undoubtedly be found of great service to field geologists, engineers, chemists, and in short all those who desire more definite and special knowledge about rocks than is found in geological text-books, and yet who do not desire to approach the subject from the difficult side of microscopical petrography. One of the chief merits of the work is that it does not attempt to tell too much by exchanging clearness for brevity. It is evident that only the broadest distinctions and simplest of classifications can be made without the use of the microscope, and that complicated methods for determining all rocks by megascopic properties must necessarily be unsatisfactory. Wisely recognizing this, the author has confined himself to telling such things about rocks as it is possible to learn without the microscope. The tables of analyses and discussions of the chemical composition are an excellent feature. The value is also greatly enhanced by a very full glossary in the end. L. V. P.

III. BOTANY AND ZOOLOGY.

1. *An Illustrated Flora of the Northern United States, Canada, and the British Possessions from Newfoundland to the Parallel of the Southern Boundary of Virginia, and from the Atlantic Ocean westward to the 102d meridian;* by NATHANIEL LORD BRITTON, Ph.D., and Hon. ADDISON BROWN. In three volumes. Vol. 1, Ophloglossaceæ to Alzoaceæ. New York, 1896 (Charles Scribner's Sons).—Believing sincerely that whatever stimulates the study of Natural History is a substantial gain, we welcome this treatise. Its typography and profuseness of illustration cannot fail to attract many readers who will use it as an agreeable introduction to the pursuit of botany. To the system of nomenclature which has been adopted, we cannot, at this stage of what promises

* This Journal, vol. l, p. 480, Dec. 1895, and vol. ii, p. 124, Aug. 1896.

to be a long discussion, give approval; in fact we do not quite understand the relation which this work sustains to the association check-list recently promulgated, nor do we favor the liberty which has been taken with many species. Critical comments relative to disputed cases can, however, be better left until the completion of the work. As the treatise appears to be in a state of promising forwardness, we may not have long to wait for the remaining volumes. We congratulate the authors on their success in conducting this work. Whatever divergence of views there may be in regard to certain descriptions, names, ranges and figures, there can be but one opinion as to the remarkable energy with which this undertaking has been carried on. The authors have made what must, in all fairness, be regarded as a very important and, we hope, useful contribution to our knowledge of American plants. The price at which this work is sold is extremely low, and should ensure its finding a place on the working table of amateurs and professional botanists throughout its range. G. L. G.

2. *Notes on the Flora of Newfoundland;* by B. L. Robinson and H. von Schrenk.—As a matter of record we call attention to this interesting paper in the January and April numbers of the Canadian Record of Science. The authors visited the island in 1894, and made such collections as were possible in the last days of July and nearly the whole of August. They added more than a hundred species which had not hitherto been recorded as found in the island. G. L. G.

3. *The Survival of the Unlike. A collection of Evolution Essays suggested by the study of Domestic Plants;* by L. H. Bailey. New York, 1896 (The Macmillan Co.).—This interesting volume takes its name from the first essay in its pages. The author holds that the unlikenesses in plants are (1) the expressions of the ever-changing environmental conditions in which plants grow, and of the incidental stimuli to which they are exposed; (2) the result of the force of mere growth; (3) the outcome of sexual mixing. They survive *because* they are unlike, and thereby enter into fields of least competition. Leaving out the second of these categories, the position is a strong one, and it is well maintained. Professor Bailey believes, and we cannot believe otherwise in view of horticultural experience, that plants can be profoundly modified by different external conditions, and that these modifications tend to persist. We are greatly indebted to the author for the untiring assiduity with which he has pursued the task of accumulating evidence and for the skill with which he marshals his proofs. G. L. G.

4. *Sphagna Boreali-Americana Exsiccata;* curaverunt D. C. Eaton et E. Faxon, New Haven, 1896.—In June, 1893, Prof. Eaton and Mr. Faxon issued a prospectus of an intended distribution of sets of North American Sphagna, but the death of Prof. Eaton in June, 1895, made it necessary for his son, Mr. G. F. Eaton, to complete the arrangement of the sets prepared by

Mr. Faxon and his father. Sixty sets, each containing 172 numbers, representing 39 species and their varieties and forms, have been prepared and form a collection indispensable to all students of Sphagna. Specimens of all the species and varieties were sent by Prof. Eaton to the well-known sphagnologist, Dr. C. Warnstorf, whose suggestions as to nomenclature have been closely followed. The specimens are remarkably fine and offer a richness of material for the study of North American forms of the genus unequalled by any previous collection. The eastern portions of the United States are very fully represented by specimens collected mainly by Mr. Faxon and Prof. Eaton. The forms from the South and West, though not so fully, are well represented by the contributions of a number of well-known collectors. The distribution of the sets is in charge of Mr. G. F. Eaton, whose address is 70 Sachem street, New Haven, to whom those desiring sets should apply for information. W. G. F.

5. *Analecta Algologica, Continuatio III.* By Prof. J. G. AGARDH. Lund., 1896, pp. 140, pl. I. 4°.—This valuable contribution forms apparently the final portion of the series of *Analecta*, since it includes an index to the whole work. The present portion covers a large field and the author gives a revision of *Punctaria* and its allies, including the new genera *Homœostroma* and *Nematophlœa;* a revision of *Phyllitis* with the new genus *Endarachne* represented by *E. Binghamiæ* from California; notes on Australian *Ecklonieæ* and revisions of the genera *Cystoseira* and *Cystophora* and the Japanese Largassa; and remarks on various *Florideæ*, including a revision of *Chylocladia* and *Liagora*. Among North American forms are several new species of *Liagora*, and the new genus *Hooperia*, founded on *Chylocladia Baileyana*, Harv. W. G. F.

6. *Phycotheca Boreali-Americana;* by F. S. COLLINS, ISAAC HOLDEN and W. A. LETCHELL.—The fifth fascicle of this series has recently been issued, and like its predecessor includes a large number of interesting Nostochineæ, 18 in all, together with Ehlorosporeæ and Florideæ. We may mention *Anabæna catenula*, var. *Americana*, *A. Barnetiana*, recently described in Erythea by Mr. Collins, *Enteromorpha cruciata* Collins, *Codium mucronatum* var. *Californicum*, and *Ceramium codicola*.

W. G. F.

7. *Ueber das Verhalten der Kerne bei den Fruchtentwickelung einiger Ascomyceten;* by R. A. HARPER.—The present paper from Pringsheim's Jahrbuecher is a continuation of one already noticed in the April number of this Journal. In that paper he gave an account of his study of the development of the perithecia of Sphærotheca, in which only a single ascus is formed. Here he extends his observations to perithecia with several asci as illustrated by *Erysiphe communio*. In this case, the fertilized egg-nucleus divides into two and then into four and the oogonium increases in length with the formation of cross-septa until it forms a curved tube with a row of from five to eight nuclei. The septa then form simul-

taneously so that the cell next to the terminal one contains two or even more nuclei. From this cell arise the hypha which are to bear the asci, although the tangle formed by the ascogenaus hyphæ is so great that it cannot be asserted with certainty that some of the hyphæ arise from the adjoining cells of the tube. The cells which ultimately form the asci can always be recognized by their large size and by having two nuclei. An account is given of the development of the perithecial wall and the conidial spores in Erysiphe. A less minute account is given of the development of the fruit in *Ascobolus*, in which the interesting point is brought out that the septa in the Ascogonium are perforated in the center. The paper closes with some very suggestive general remarks on the relation of the fertilization in Ascomycetes to that in Florideæ. The union of nuclei in asci and basidia, which has been considered a sexual act by a number of recent writers, is not so interpreted by Dr. Harper. In the Erysipheæ, at least, the real sexual process is found in the union of the nuclei of the antheridum and the oözonium. W. G. F.

8. *A gigantic Cephalopod on the Florida coast.*—Mr. R. P. Whitfield has forwarded to the writer the following letter from Dr. Webb to Mr. J. A. Allen, dated St. Augustine, Fla., Dec. 8th, 1896:

"You may be interested to know of the body of an immense Octopus thrown ashore some miles south of this city. Nothing but the stump of the tentacles remain, as it had evidently been dead for some time before being washed ashore. As it is, however, the body measures 18 feet in length by 10 feet in breadth. Its immense size and condition will prevent all attempts at preservation. I thought its size might interest you, as I do not know of the record of one so large."

The proportions given above indicate that this may have been a squid-like form and not an *Octopus*. The "breadth" is evidently that of the softened and collapsed body, and would represent an actual maximum diameter in life of at least 7 feet, and a probable weight of 4 to 5 tons for the body and head. These dimensions are decidedly larger than those of any of the well-authenticated Newfoundland specimens. It is perhaps a species of *Architeuthis*. Professor Steenstrup recorded many years ago a species of this genus (*A. dux*),* taken in 1855 in the West Indian seas, but his example was much smaller than the one here recorded.

A. E. VERRILL.

IV. Miscellaneous Scientific Intelligence.

1. *A History of Elementary Mathematics, with hints on methods of teaching;* by Florian Cajori, Ph.D., Professor of Physics in Colorado College. pp. 304. New York, 1896 (The Macmillan Company).—A book which presents the most important part of the history of mathematics in a form attractive

* See Trans. Connecticut Acad., vol. v. Also Report U. S. Fish Commis. for 1879, p. 51, pl. 12, fig. 4.

to laymen is worthy of a hearty welcome. Many excellent histories are to be found on the shelves of our libraries, but few, if any, are sufficiently elementary and untechnical to tempt any but the trained mathematician.

As far as Arithmetic, Algebra, Geometry and Trigonometry are concerned, few will have occasion to go beyond this book, and those few will find all necessary directions in its copious footnotes and references.

One main purpose of the author, as avowed in the preface, is to offer suggestions for the guidance of teachers based on the sound principle that "the education of the child must conform both in mode and arrangement with the education of mankind, as considered historically;" but the chief benefit to be derived from it by any reader, whether he be a teacher or not, consists in the stimulating and liberalizing effect of such a general view of the development of the human intellect in a direction where that development has been so free and characteristic. Any student with the training of the average freshman can read the book with profit, and many a student who has traveled from the multiplication table to spherical triangles as through a dry and thirsty land, would by such reading be brought to see a new meaning in the region through which he has come and even to find it full of dignity and beauty as the scene of the labor and achievement of so many centuries. W. B.

2. *An Eclipse Party in Africa: Chasing Summer Across the Equator in the U. S. S. Pensacola;* by EBEN J. LOOMIS, Senior Assistant U. S. Nautical Almanac Office. 218 pp. Boston, 1896 (Robert Brothers).—The Scientific results of the American Solar Eclipse Expedition to Africa in the latter part of the year 1889 have already been presented in a number of scientific journals. It has remained for Mr. Loomis to give a popular account of the experiences of the party. This he does in a most attractive way in the present volume. The reader starts off with the U. S. S. *Pensacola* from Brooklyn, on the 16th of October, and has a delightful journey to the Azores, the Cape Verde Islands, and along the west coast of Africa to St. Paul de Loanda and Cape Ledo, where the party disembarked and the astronomical instruments were set up for use. An interesting account follows of the course of the eclipse, unfortunately not observed under the best conditions for scientific results; when the work there was through, the journey was continued to Cape Town and then back by St. Helena, the Ascension Islands and the Barbadoes to the starting point, which was reached May 23, 1890. A side trip to the Kimberley diamond mines afforded the writer a chance to give an account of the many things of interest which he saw and learned there. Indeed, the volume is throughout both entertaining and instructive, and its interest is much increased by the large number of excellent half-tone plates, chiefly from photographs taken by members of the expedition.

3. *Elementary Meteorology for High Schools and Colleges;* by FRANK WALDO, Ph.D. 373 pp. 12mo. New York, 1896.

(American Book Company).—This new elementary text-book, in a department in which the teacher has thus far had but little choice open to him, can be heartily commended. The author's practical experience in connection with the Weather Bureau has aided him in presenting the fundamental facts and principles of the science clearly and systematically and with all needed illustration. The treatment is brief, as must necessarily be the case in a book so limited in size, but this does not seem to have impaired the accuracy of the statements. Detailed descriptions of instruments have been wisely omitted. The figures are numerous and good.

4. *The Meteor of December 4th.*—A meteor, of unusual size and brilliancy, was observed from numerous points in southern New England and New York on the afternoon of December 4th, shortly after half past four o'clock. An observer in Brooklyn (Mr. Gustav Müller) gives the time of its appearance as $4^h\ 41{\cdot}1^m$, the direction E.N.E., and the course nearly vertical downward with a slight curvature to the north from an altitude of 50° to 20° when it disappeared, apparently obscured by clouds. He estimated the duration as from 2 to 3 seconds; the form was that of an elongated ovoid; a bluish or greenish tinge of color in the blazing mass was noted. From New Haven, Conn., the meteor appeared at sensibly the same hour in a direction about E.S.E.; the same brilliant color was noted, but the sky was partially obscured by clouds. The observations recorded suggest that the mass may have fallen in the eastern part of Long Island Sound.

Obituary.

Benjamin Apthorp Gould. In the death of Dr. Gould, which occurred at his home in Cambridge, Mass., on the evening of November 6, 1896, science has suffered a heavy loss. Though for the past two years his health had been seriously impaired from the effects of an accident, he was still able to accomplish an amount of work which might have satisfied many younger men; and he enjoyed the capacity to work up to the day of his death.

Benjamin Apthorp Gould was born in Boston, September 7, 1824. Descended from a line of educated men, he was carefully trained in the classics and the humanities. During his whole life he continued to cultivate his mind with the wit and philosophy of all ages, wherein he seemed to find his keenest enjoyment. Joined to these attainments was that of an accomplished linguist; thus he was not only a man of ripe and accurate scholarship, but he was a cosmopolitan as well.

Soon after his graduation from Harvard College in 1844, he spent about three years in Europe, visiting in turn the most important astronomical observatories, in order to obtain instruction in astronomy from the acknowledged masters of that science. Thus he acquired not only a high degree of professional training, but he was also enabled to transplant to this country the inherited traditions of astronomical science, which are so valuable in obtaining a proper perspective over the history of astronomy and as an aid to the guidance of its future.

While Dr. Gould was a citizen of the world, and corresponded with his intimate friends in at least four different languages, he was most intensely devoted to the promotion of science in his native land. As one means to this end he established the *Astronomical Journal* in 1848. He sustained its publication to a large extent from his own private means, and he lavished upon it earnest solicitude and unremitting care to make of it a worthy representative of American science as well as a record of valuable scientific investigations. Though Dr. Gould was obliged to suspend the publication of the Astronomical Journal from 1861 to 1886, this periodical had entered upon its seventeenth volume at the time of his death, established more firmly than ever as the organ of American astronomy.

There is not space here to mention all the important scientific works and occupations of Dr. Gould, even in outline. The most notable may receive passing notice. From 1852 to 1867 he was in charge of telegraphic longitude determinations for the U. S. Coast Survey. He developed the methods employed, and determined the first transatlantic longitude by telegraph. During the Civil war, while in the service of the Sanitary Commission, he pursued extensive investigations in Anthropometry, the results of which he published. Also, during the period 1848 to 1870, he effected the reduction of various extended series of astronomical observations, — notably the meridian observations made by D'Agelet in Paris near the close of the last century.

His great and distinctive work, however, is comprised in the survey of the southern sky which occupied him during the period from 1870 to 1885. During this time he secured the founding and directed the labors of a National Observatory at Cordoba in the Argentine Republic. Here, with immense industry, and with a perseverance which remained undaunted in the face of great obstacles and personal afflictions, he completed a critical and exhaustive uranometry of the southern sky, and he supplemented the zone-observations of Bessel and Argelander by his own observations of 73,160 stars south of $-23°$ of declination, much surpassing these predecessors in the precision of measurement attained. Besides these labors, his catalogue of 32,448 of the brighter stars in the Southern hemisphere contains the results of more than 150,000 meridian observations of precision,—a work which has not been equalled in extent, nor surpassed in value, by any other similar work in astronomy.

Dr. Gould, in coöperation with Mr. Rutherfurd, was a pioneer in developing the application of photography to astronomy of precision. He made extensive use of celestial photography during his stay in South America. The elaboration of this material in an extensive memoir, which he left substantially complete, was the last great undertaking of his life.

He was one of the founders of the National Academy of Sciences. He was elected an honorary member of the principal Academies of Science in Europe; he became a knight of the order *pour le mérite* of the German Empire; and he received other honors and medals too numerous to admit of mention here.

L. B.

CATALOGUE

OF THE

COLLECTION OF METEORITES

IN THE

PEABODY MUSEUM OF YALE UNIVERSITY.

METEORIC STONES.

	Date of Fall.	Locality and Catalogue Number.	Weight in grams.	
			Largest mass.	Total.
1	1492, Nov. 16	Ensisheim, Elsass, Germany (1).	13	18
2	1768, Nov. 20	Mauerkirchen, Upper Austria (76).	12	12
3	1790, July 24	Barbotan, Landes, France (55).	15	15
4	1794, June 16	Siena, Tuscany, Italy (77).	6	7
5	1798, Dec. 19	Benares (Krakhut), Bengal, India (2).	1	1
6	1803, April 26	L'Aigle, Orne, France (3).	902	902
7	1807, Dec. 14	Weston, Connecticut (4).	14,625	14,880
8	1808, April 19	Parma (Borgo San Donino), Italy (5).	10	10
9	1808, May 22	Stannern, Iglau, Moravia (6)	76	107
10	1810, Nov. 23	Charsonville, Loiret, France (7).	9	9
11	1811, July 8	Berlanguillas, Burgos, Spain (8).	14	14
12	1812, April 15	Erxleben, Magdeburg, Prussia (48).	13	13
13	1812, Aug. 5	Chantonnay, Vendée, France (9).	39	42
14	1814, Feb. 14	Bakhmut (Alexejewka), Russia (10).	2	2
15	1814, Sept. 5	Agen, Lot-et-Garonne, France (61).	7	7
16	1815, Feb. 18	Durala, Punjaub, India (11).	3	3
17	1818, Aug. 10	Slobodka, Smolensk, Russia (12).	2	2
18	1819, June 13	Jonzac, Charente Inférieure, France (13).	2	2
19	1822, Nov. 30	Futtehpur, N. W. Provinces, India (14).	36	36
20	1822-23	Umballa, Punjaub, India (15).	1	1
21	1823, Aug. 7	Nobleboro, Lincoln Co., Maine (78).	7	7
22	1825, Feb. 10	Nanjemoy, Charles Co., Maryland (16).	897	897
23	1825, Sept. 15	Honolulu, Hawaii, Sandwich Islands (17).	577	577
24	1827, May 9	Drake Creek (Nashville), Tennessee (18).	425	425
25	1828, June 4	Richmond, Virginia (19).	311	311
26	1829, May 8	Forsyth, Monroe Co., Georgia (20).	132	132
27	1831, May 13	Vouillé, near Poitiers, France (21).	5	5
28	1838, Aug. 18	Akburpur, Saharanpur, India (22).	1	1
29	1838, June 6	Chandakapur, Berar, India (23).	41	41
30	1838, Oct. 13	Cold-Bokkeveldt, Cape of Good Hope (24).	96	110
31	1839, Feb. 13	Little Piney, Pulaski Co., Missouri (25).	24	24
32	1841, June 12	Chateau Renard, Loiret, France (26).	91	91
33	1842, April 26	Milena (Miljana) Warasdin, Croatia (63).	7	7
34	1843, Mar. 25	Bishopville, Sumter Co., So. Carolina (28).	211	211
35	1843, June 2	Utrecht, (Blaauw-Kapel). Holland (27).	4	4
36	1845, Jan. 25	Le Pressoir, Indre-et-Loire, France (80).	4	4
37	1846, May 8	Monte Milone, Macerata, Italy (29).	3	3
38	1846, Aug. 14	Cape Girardeau, Missouri (67).	1,495	1,637
39	1847, Feb. 25	Linn Co (Hartford), Iowa (30).	666	1,062
40	1848, May 20	Castine, Hancock Co., Maine (79).	16	16
41	1849, Oct. 31	Cabarras Co. (Monroe), North Carolina (31).	231	231
42	1850, June 13	Kesen, Iwate, Japan (81).	424	424
43	1850, Nov. 30	Shalka, Bancoora, Bengal, India (32).	1	1
44	1851, April 17	Gütersloh, near Minden, Westphalia (33).	4	4
45	1852, Jan. 23	Nellore, (Yatoor), Madras, India (34).	27	47
46	1852 Sept. 4	Mezö-Madaras (Fekete), Transylvania (35).	20	20
47	1852, Dec. 2	Bustee, near Goruckpur, India (82).	12	12

METEORIC STONES—*Continued.*

	Date of Fall.	Locality and Catalogue Number.	Weight in grams.	
			Largest mass.	Total.
48	1853, Mar. 6	Segowlee, Bengal, India (36).	46	46
49	1855, May 11	Oesel Island, Livonia, Russia (37).	6	6
50	1855, Aug. 5	Petersburg, Lincoln Co , Tennessee (49).	15	15
51	1856, Nov. 12	Trenzano, Brescia, Italy (83).	43	43
52	1857, Feb. 28	Parnallee, Madras, India (38).	944	1,956
53	1857, April 15	Kaba, Debreczin, Hungary (84).	0.5	0.5
54	1858, Dec. 9	Aussor (Montrejeau), Hte. Garonne, France (59)	18	18
55	1859, Mar. 28	Harrison County, Indiana (39).	17	17
56	1859, July 4	Miney, Taney Co., Missouri (99). Newton Co., Arkansas (52).	67 7	67 7
57	1860, May 1	New Concord, Guernsey Co., Ohio (40).	6,718	6,718
58	1860, July 14	Dhurmsala, Punjaub, India (68).	38	38
59	1861, May 12	Butsura (Qutahar Bazaar), Bengal, India (41).	92	92
60	1863, June 2	Buschhof, Kurland, Russia (42).	22	22
61	1863, Aug. 8	Pillistfer, Livonia, Russia (43).	11	11
62	1863, Dec. 7	Tourinnes-la-Grosse, Tirlemont, Belgium (64).	4	4
63	1863–64	Tomhannock Creek, Rensselaer Co., N.Y. (75).	15	15
64	1864, April 12	Nerft, Kurland, Russia (44).	48	48
65	1866, June 9	Knyahinya, Unghvar, Hungary (60).	41	65
66	1867, June 9	Tadjéra, Sétif, Algeria (100).	44	44
67	1868, Jan. 30	Pultusk (Sielce), Poland (45).	177	394
68	1868, Nov. 27	Danville, Morgan Co., Alabama (51).	11	11
69	1869, Dec. 5	Frankfort, Franklin Co., Alabama (46).	185	217
70	1869, found	Near Salt Lake City, Utah (69).	785	785
71	1869, Jan. 1	Hessle, near Upsala, Sweden (58).	39	39
72	1869, May 5	Krähenberg, Zweibrücken, Palatinate (50).	2	2
73	1869, May 22	Cléguérec (Kernouve), Morbihan, France (47).	13	13
74	*ca.* 1870	Rockport, Texas (95).	105	105
75	1871, May 21	Searsmont, Waldo Co., Maine (53).	10	10
76	1872, July 23	Lancé (Authon), Loir-et-Cher, France (101).	27	27
77	1873, June	Jhung, Punjaub, India (72).	16	16
78	1873, Sept. 23	Khairpur, Bhawalpur, India (85).	10	10
79	1874, found	Waconda, Mitchell Co., Kansas (62).	54	123
80	1874, May 14	Castalia, Nash Co., North Carolina (70).	247	247
81	1875, Feb. 12	Iowa County (Homestead), Iowa (56).	11,960	35,719
82	1876, Dec. 21	Rochester, Fulton Co., Indiana (58).	15	15
83	1877, Jan. 3	Warrenton, Warren Co., Missouri (57).	106	260
84	1877, Oct. 13	Sako-Banja, Sarbanovac, Servia (66).	2	2
85	1878, found	Fayette County (Bluff), Texas (87).	434	774
86	1878, Nov. 20	Rakovka, Tula, Russia (65).	0.3	0.3
87	1879, July 1	Nagaya, Entre Rios, Argentina (86).	4	10
88	1882, Feb. 2	Baré, Möcs, Transylvania (71a). Möcs, Transylvania (71bc).	50 104	50 123
89	1883, Feb. 16	Alfianello, Brescia, Italy (73).	100	175
90	1884, Mar. 19	Djati-Pengilong, Java (88).	250	250
91	1887, found	Rockwood (Crab Orch'd), Roan Co., Tenn (90a) Powder Mill Cr'k, Cumberland Co., " (90b)	96 17	96 17
92	1887, Aug. 30	Taborg, Ochansk, Perm, Russia (89).	10	10
93	1887, found	Morristown, Hamblen Co., Tennessee (98).	114	114
94	1887, found	Pipe Creek, Brandena Co., Texas (97).	49	49
95	1888, found	Llano del Inca, Atacama, Chile (91).	46	46
96	1888, found	Doña Inez, Atacama, Chile (92).	53	53
97	1890, May 2	Winnebago County, Iowa (93).	3,200	27,730
98	1890, June 25	Farmington, Washington Co., Kansas (94).	216	247
99	1892, Aug. 29	Bath, South Dakota (96).	126	126

Meteoric Irons.

	Date of Discovery.	Locality and Catalogue Number.	Weight in grams.	
			Largest mass.	Total.
100	Prehistoric	Turner Mounds, Anderson, Ohio (85).	6	6
101	{ 1751, fall 1164 { 1847, fall 1164	Steinbach, Erzgebirge, Saxony (2). Rittersgrün, Erzgebirge, Saxony (71).	1 23	2 23
102	1811, fall 1400	Elbogen, Bohemia (7).	8	8
103	1749	Krasnojarsk, Siberia (3)—"Pallas Iron."	1,327	1,780
104	1751, May 26 fall	Agram, Hraschina, Croatia (1).	3	3
105	*ante* 1776	Xiquipilco, Toluca, Mexico (4).	880	900
106	*ante* 1776	Ixtlahuaca, Toluco, Mexico (87).	992	1,883
107	*ante* 1780	Descubridora.Catorze,San Luis Potosi, Mx.(58)	195	195
108	1784	Bemdego, Bahia, Brazil (86).	162	162
109	1793	Cape of Good Hope, South Africa (5).	8	12
110	*ca.* 1807	Bitburg (Albacher Mühle), Eifel, Prussia (8).	58	63
111	1808	Red River, Texas (6).	740 kilos	
112	1810	Tocavita (Santa Rosa), Colombia, S. A. (78).	2	2
113	——	Colombia, South America (51).	57	57
114	1814	Lenarto, Saros, Hungary (9).	120	120
115	1818	Lockport (Cambria), New York (10).	2,715	2,715
116	*ante* 1819	Burlington, Otsego Co., New York (11).	738	738
117	1820	Guilford County, North Carolina (12).	20	20
118	1822	Imilac, Atacama Desert, Chile (13).	178	278
119	1827	Newstead, Roxburghshire, Scotland (44).	96	96
120	1827	Sanchez Estate, Santa Rosa, Coahuila (84).	380	380
121	1829	Bohumilitz, Prachin, Bohemia (14).	37	37
122	1832	Walker County, Alabama (23).	350	354
123	1834	Claiborne (Lime Creek), Alabama (15).	64	64
124	1834	Scriba, Oswego County, New York (19).	173	173
125	1835, Aug. 1 fall	Charlotte, Dickson County, Tennessee (38).	2	2
126	*ante* 1836	Wichita County (Brazos River), Texas (89).	167	169
127	1837	Coahuila, Bolson de Mapini, Mexico (64).	1,508	2,810
128	——	Chihuahua, Mexico (49).	51	51
129	1839	Putnam County, Georgia (16)	294	380
130	*ante* 1840	Cosby's Creek, Cooke Co., Tennessee (17).	934	977
131	1840	Arva (Magura), Hungary (18).	826	1,126
132	1840	Tarapaca, Hemalga, Chile (76).	17	17
133	*ca.* 1844	Carthage (Coney Fork), Tennessee (24).	104	104
134	*ante* 1845	Carysfort, De Calb Co., Tennessee (21).	61	61
135	1845	Saint Augustine's Bay, Madagascar (22).	7	7
136	1846	Netschaëvo, Tula, Russia (69).	31	31
137	*ante* 1847	Seeläsgen, Brandenburg, Prussia (25).	174	174
138	1847, July 14 fall	Braunau (Hauptmannsdorf), Bohemia (90).	10	11
139	*ante* 1849	Chesterville, Chester Co., So. Carolina (27).	758	758
140	*ante* 1850	Pittsburg, Pennsylvania (26).	213	213
141	*ante* 1850	Salt River, Kentucky (29).	985	985
142	*ante* 1850	Ruff's Mountain, Lexington Co., N. C. (30).	536	536
143	1850	Schwetz, Prussia (28).	256	256
144	1851	Seneca Falls, Cayuga Co., New York (31).	378	378
145	*ante* 1851	Tucson, Arizona, "Signet Iron" (83).	205	205
146	*ante* 1851	Tucson, Arizona, "Carleton Iron" (37).	158	158
147	1852	Poplar Hill, Cranberry Plains, Va. (62).	21	21
148	*ante* 1853	Lion River, Gt. Namaqualand, So. Africa (33).	40	40
149	1853	Tazewell, Claiborne Co., Tennessee (34).	418	418
150	1853	Union County, Georgia (65).	15	15
151	1854, 1873	Jewell Hill (Duel Hill), Madison Co., N. C.(41).	5,610	5,676
152	1854	Oktibbeha County, Mississippi (36).	1	1
153	1854	Madoc, Ontario, Canada (35).	26	26

METEORIC IRONS—*Continued.*

	Date of Discovery.	Locality and Catalogue Number.	Weight in grams.	
			Largest mass.	Total.
154	1854	Cranbourne, Victoria, Australia (56).	103	103
155	*ante* 1856	Orange River, South Africa (39).	27	27
156	1856	Denton County, Texas (42).	66	66
157	1856	Fort Pierre, South Dakota (43).	343	343
158	1856	Hainholtz, Minden, Westphalia (38).	8	8
159	1858	Augusta County (Stanton), Virginia (77).	885	885
160	1858	Trenton, Washington Co., Wisconsin (57).	65	113
161	1860	Nelson County, Kentucky (40).	112	112
162	1860	Lagrange, Oldham Co., Kentucky (60).	46	46
163	1860	Coopertown, Robertson Co., Tennessee (45).	115	115
164	*ante* 1861	Sierra de Chaca (Vaca Muerta), Atacama (72).	40	40
165	1862	Colorado River, La Paz, New Mexico (46).	11	11
166	*ante* 1863	Southeast Missouri (47).	68	68
167	*ante* 1863	Dakota (48).	4	4
168	1863	Russell Gulch, Gilpin Co., Colorado (55).	126	126
169	1863	Obernkirchen, Schaumburg-Lippe, Ger. (91).	89	89
170	1863, fall	Nejed, Central Arabia (92).	30	30
171	1866	Bear Creek, Denver, Colorado (53).	151	157
172	1866	Frankfort, Franklin Co., Kentucky (54).	37	37
173	1867	Arizona, exact locality unknown (52).	31	31
174	1867	Scotsville, Allen Co., Kentucky (80).	41	74
175	1868	Losttown, Cherokee Co., Georgia (93).	3	3
176	1869–70	Shingle Springs, Eldorado Co., Cal. (59).	603	635
177	1872	Nenntmannsdorf, Pirna, Saxony (66).	47	47
178	*ante* 1875	Butler, Bates Co., Missouri (73).	970	970
179	1875	Santa Catarina (Morro do Ricio), Brazil (67).	720	1,661
180	1877	Dalton, Whitfield Co., Georgia (94).	33	33
181	1879, May 10 fall	Estherville, Emmet Co., Iowa (74).	41,960	48,175
182	1880	Ivanpah, San Bernardino Co., Cal. (70).	4	4
183	1880	Lexington Co., South Carolina (68).	49	49
184	1880	Eagle Station, Carroll Co., Kentucky (95).	70	70
185	1882	Hex River Mts., Cape Colony, S. Africa (108).	46	46
186	1883	Grand Rapids, Michigan (82).	638	678
187	1883	Hammond, St. Croix Co., Wisconsin (96).	22,730	23,640
188	1883	Plymouth, Indiana (105).	111	111
189	1884	Puquios, Chile (110).	24	24
190	1884	Glorieta Mt., Santa Fe Co., New Mexico (79).	2,840	3,970
191	1884	Independence Co. (Joe Wright Mt.), Ark.(97).	103	103
192	*ca.* 1886	Kiowa County, Kansas (102).	46,137	46,137
193	1886	Thunda, Queensland, Australia (106).	64	64
194	1887	Silver Crown, Laramie Co., Wyoming (109).	46	46
195	*ante* 1888	Bella Roca, Durango, Mexico (99).	332	332
196	1888	Hamilton Co., Texas (100).	173	173
197	1888	Welland, Ontario, Canada (104).	58	58
198	*ante* 1889	Kenton Co. (Independence), Kentucky (101).	5,698	5,698
199	1890	Bridgewater Station, Burke Co., N. C. (107).	19	19
200	1891	Cañon Diablo, Arizona (103).	375450	383,000
201	1894	Cherokee Mills, Georgia (111).	89	89

The last catalogue of the meteorites preserved in the Mineralogical Collection of Yale University was published in 1886. At that time the total number of catalogued specimens, both stones and irons, amounted to 147, an increase of 45 over the last previous catalogue of 1869. At the present time (1896) the total number of falls represented is 201, an increase of 37 per cent. The total weight of the stones is about 100 kilos, of the irons 1274 kilos, in all 1374 kilos (about 3025 pounds), an increase of 53 per cent.

The largest specimen in the collection is still the well known iron from Red River, Texas, which weighs 740 kilos (1,635 lbs.). The next largest is a fine mass of the Cañon Diablo, Arizona, iron, which weighs 375 kilos (826 lbs.). This was presented to the collection as a memorial of Prof. Elias Loomis by his sons and friends. Another large mass is that of the Kiowa County, Kansas, a pallasite, which weighs 46 kilos (102 lbs.). This is one of a number discovered about 1886; it was presented by E. M. Reed and Pierce N. Welch. A notable mass, also, is that discovered in 1883 at Hammond, St. Croix County, Wisconsin, which was presented by Prof. H. A. Newton. This weighed originally some 25 kilos (55 lbs.), but pieces have been cut off for purposes of exchange, the large mass at present weighing 23 kilos (50.6 lbs.). In the present catalogue the fall of May 10, 1879, in Emmet County, Iowa, is classed among the irons. Representing this fall are nearly six hundred complete specimens, the largest weighing 42 kilos (nearly 100 lbs.), the smaller ranging from those weighing a pound down to those of the size of a pea. Among the irons may also be mentioned a small slice of the meteoric iron which was found in 1883 on the altar of one of the "Turner" Indian mounds, in the Little Miami Valley, Ohio. This was presented by Prof. H. A. Newton. It has since been shown that these fragments are probably derived from masses of the Kiowa County fall just mentioned.

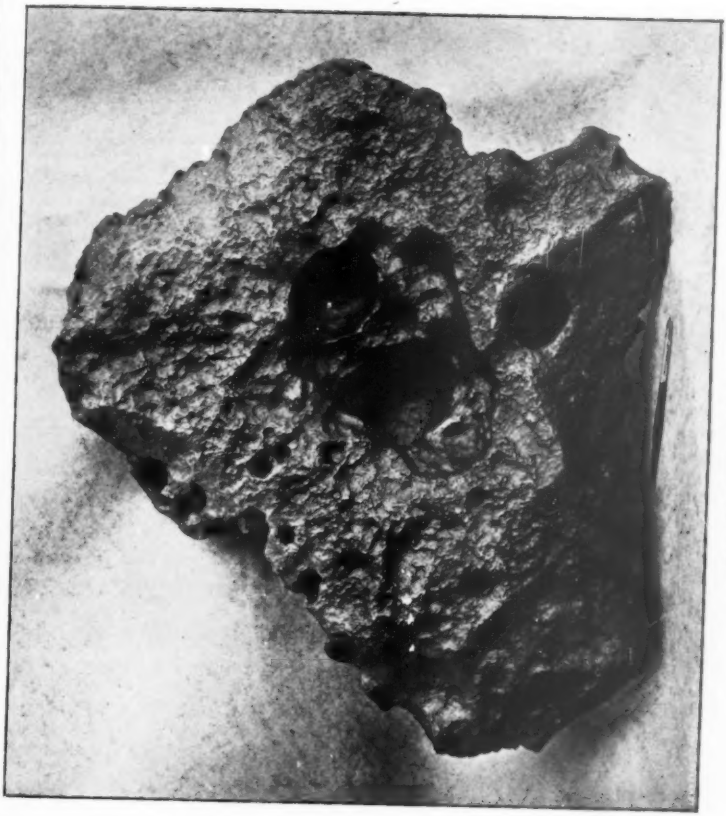
Among the stones the most important addition is the collection from the fall of May 2, 1890, in Winnebago County, Iowa, which was presented by Henry K. and Alice F. English. This collection numbers between 900 and 1,000 separate stones, most of them perfect, and is one of the largest collections from a single fall that exists in any museum. Another notable fall is that of Feb. 12, 1875, in Iowa County, Iowa, which contains 20 stones, eight of them weighing more than a kilo, and the largest weighing about 12 kilos. Other large stones in the collection are those of Weston, Connecticut; Guernsey Co., Ohio; Cape Girardeau, Missouri; and Salt Lake City, Utah. A slice of the interesting stone which fell March 19, 1884, at Djati-Pengilong, Java, which was presented by the Dutch government, may also be mentioned.

It is desired to increase the collection as opportunity offers and to make it as complete as possible. Any communication having this end in view, either by gift, purchase or exchange, may be addressed to Prof. E. S. Dana, Curator of the Collection, at New Haven, Conn.

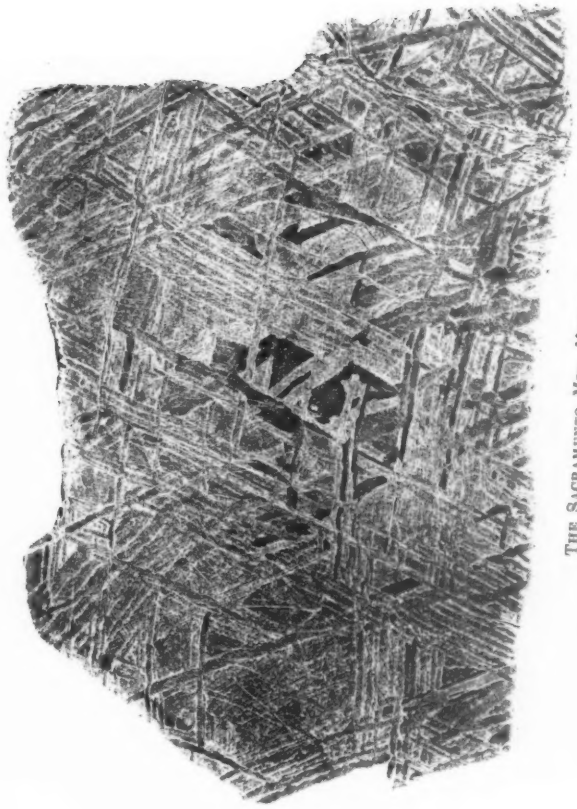
HENRY S. WASHINGTON.

June, 1896.

NOTE.—The last list of the meteorites in the British Museum by L. Fletcher has been in general followed in the preparation of this Catalogue. Since its completion the list of the Vienna collection by Brezina has been received. It should be noted that Brezina shows that the irons of Jewell Hill (1854) and of "Duel Hill" (No. 151 above) are probably distinct.



THE SACRAMENTO MTS. METEORITE
(One eighth full size.)



THE SACRAMENTO MTS. METEORITE.
(Printed directly from the etched surface of the iron.)